
Bentall Kennedy

Final Report

# The Lakes District and Schooner Cove ISMP

November 21, 2013

Submitted by:

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Regional District of Nanaimo

Dear Sirs/Madam:

**RE: BENTALL KENNEDY**
**The Lakes District and Schooner Cove ISMP**
**Final Report Submission**
**Our File 2964.002**

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On behalf of our client Bentall Kennedy, please find attached the Final Report for *The Lakes District and Schooner Cove Integrated Stormwater Management Plan*. This report incorporates new sections based on the comments provided by Urban Systems (Letter dated October 31, 2013), namely:

- Impact of Water Licence Withdrawals on Enos Lake Water Levels in Section 3.3
- Climate Change Sensitivity Analysis in Section 3.6 and Appendix A.3
- Continuous Simulation Modelling for Rain Garden Sizing Subsection and Stormwater Pollutants & Rain Garden Removal Efficiencies in Section 3.8
- Hydrologic Impact to Wetlands in Section 3.9
- Roadside Rain Gardens in Section 4.2 (including Proposed Road Slopes in Fairwinds, Silver Ridge Residential Subdivision Example, and Design Lessons Learned)
- Table 1: Fairwinds ISMP Performance Indicators in Section 4.2

Providing a comprehensive approach based on the best management practices, the ISMP facilitates development while protecting the environment. It integrates land-use planning with stormwater engineering, flood and erosion protection, and environmental protection for the Lakes District and Schooner Cove.

The ISMP consists of many components, but of key note are:

- Conserving wetlands, watercourses, riparian and environmentally sensitive areas; and
- Implementing best management practices to minimize and mitigate the impacts of future development.

To expedite the review process, we are happy to facilitate a discussion with you and your consultant Urban Systems, as appropriate. We are available immediately at your convenience.

Yours truly,
**KERR WOOD LEIDAL ASSOCIATES LTD.**

Crystal Campbell, P.Eng.
Project Manager

Attach.
cc: Maurice Mauch, Randy Alexander, Mike Donnelly, Russell Tibbles, Rob Warren, Paul Fenske, Jeanette Elmore, Matt Hammond, Susan Wilkins, Jim O'Brien

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# 1. Introduction

The Lakes District and Schooner Cove Neighbourhood Plans (policy 4.3.3.a) required an Integrated Stormwater Management Plan (ISMP) to be completed as a component of the Zone Amendment applications for the Fairwinds Lakes District and Schooner Cove area. An ISMP is a process of investigating stormwater issues in a holistic approach at the watershed scale. It is a multi-disciplinary approach that integrates science and engineering with land-use planning, community values and environmental protection. Watershed decision-making is best accomplished after gathering and analyzing information, defining environmental values, land-use planning and stormwater options, evaluating those options in terms of quantifiable hydrologic and environmental benefits, and identifying performance measures. Community values help determine the appropriate balance between development and the environment and these are laid out in RDN policy including Lakes District Neighbourhood Plan (Nanoose Bay Official Community Plan).

The subject area is located on the east coast of Vancouver Island north of Nanaimo, as shown on Figure 1. There are two distinct study areas:

- **Fairwinds Lake District Neighbourhood** is a hilly 286 ha site with 12 small watercourses, 9 wetlands, and Enos Lake which ultimately drains to Bluefin Bay in the Strait of Georgia. The area is currently undeveloped with a few roads and trails. It is mostly forested and has unique environmentally sensitive areas such Garry Oak meadows and ecosystems. The watercourses are not fish bearing, but provide nutrient sources and habitat to stickleback fish in Enos Lake.
- **Schooner Cove Neighbourhood** is 11 ha adjacent to the ocean. It is partially developed with a small decommissioned hotel, condominium, breakwater and marina.

An extensive Environmental Impact Assessment and Neighbourhood Plans process has been adopted in 2011. A list of background reports is included in Appendix A. Plans for future development include residential units with a marina, small village and community centre converting total impervious area in the Enos Creek watershed from 17% to 36% and the Dolphin Lake watershed from 22% to 43%.

## 1.1 ISMP Vision, Goals, and Objectives

The vision established within *The Lakes District Neighbourhood Plan* is to sensitively integrate growth through principles of sustainability and community design. The plan provides for diverse housing forms structured around a network of regionally significant parks. It reconciles land use, environmental, servicing, transportation and economic considerations in a manner that respects the local community values. The character of the community is defined by the relationship between the built form and the surrounding landscape.

### ISMP Vision - Balancing Land Development & Environmental Values

The ISMP process facilitates development while protecting the environment: it integrates land-use planning with stormwater engineering, flood and erosion protection, and environmental protection. This process balances the expectations of local citizens, local governments, and regulatory agencies. It considers community values and objectives, and incorporates them into the ISMP.

The goal of the ISMP is to strive to protect the existing ecological health of the Fairwinds area aquatic resources (watercourses, wetlands, lakes and ocean) that are strongly valued by stakeholders.

### ISMP Goals, Objectives

The objectives of the study are:

- Safeguard human life and property from flood and erosion damage.
- Preserve watershed ecological health while allowing development to proceed.
- Employ green infrastructure by utilizing innovative best practices for rainwater management.
- Conserve ecological integrity by protecting both significant aquatic species and habitats.
- Develop cost effective solutions (capital, operation, and maintenance).

The ISMP must be approved by the Regional District of Nanaimo.

## 1.2 Stormwater, Drainage & Environmental Protection Criteria

Governing guidelines and criteria are based on the following and are summarized in Table 1:

- Stormwater Planning, A Guidebook for B.C., MOE, May 2002.
- Develop with Care 2012: Environmental Guidelines for Urban and Rural Land Development in British Columbia, MOE, 2012.
- Ministry of Transportation & Infrastructure (MOTI) 2007 *BC MoT Supplement to TAC Geometric Design Guide, Section 1000, Hydraulics Chapter* – details in Appendix A, Section A.2
- Riparian Areas Regulation (RAR), 2006.

**Table 1: Summary of Stormwater Management Criteria**

| Application | | Criteria/Methodology |
|---|---|---|
| Flood & Erosion Protection | Minor Drainage System | 10-year return period design event. [1] |
| | Major Drainage System | 100-year return period design event. [1] |
| Environmental & Erosion Protection | Volume Reduction 💧 | On-site rainfall capture (runoff volume reduction) to meet existing conditions up to 50% mean annual rainfall (50% of the 2-year 24-hour storm). [2] |
| | Water Quality Treatment ❋ | Remove 80% of Total Suspended Solid based on 50 µm particle size from 6-month 24-hour storm (72% of the 2-year 24-hour storm). [2]<br>Limit construction discharge water quality to the lesser of turbidity of 25 NTU or total suspended solids of 25 mg/L at all times expected in the 24 hour period following significant rainfall events (≥25 mm/day) at which time the turbidity can be up to 100 NTU. [3] |
| | Rate Control 💧 | Detain post-development flows to pre-development levels for 50% MAR[3], and 2-year 24-hour event [3] and 5-year 24-hour event.[1] |
| | Riparian ❋ | Establish riparian setbacks to comply with RAR requirements. [4] |

1. MOTI, 2007
2. Stormwater Planning, A Guidebook for B.C., MOE, May 2002
3. Land Development Guidelines for the Protection of Aquatic Habitat, Fisheries and Oceans Canada, September 1993.
4. Riparian Areas Regulation (RAR), 2006

❋ Apply to all water bodies – streams, wetlands, lakes, ocean
💧 Apply to streams susceptible to erosion

## 1.3 Stakeholder Consultation Program

An extensive stakeholder consultation process was undertaken through the Neighbourhood Planning process and continues through the Zone Amendment (ZA) and Phased Development Agreement (PDA) process. Stakeholders include the following:

- Regional District of Nanaimo staff.
- Community Advisory Group representing the Fairwinds Community Association, Nanoose Naturalists, Schooner Cove Yacht Club, Fairwinds Golf Society, Nanoose Property Owners & Residents Association, North West Nanoose Residents Association, Nanoose First Nation, Nanaimo First Nation, Regional District of Nanaimo Planning Department and Recreation & Parks Department, and Members at Large.
- First Nations – Snuneymuxw (Nanaimo) and Snaw-Naw-As (Nanoose),
- Technical Advisory Committee including RDN Planning, Recreation & Parks, Engineering, BC Ministry of Transportation and Infrastructure, BC Ministry of Environment, and Canadian Department of Fisheries and Oceans.

There were three Public Open Houses, two Public Design Workshops, regular meetings with the Community Advisory Group, Technical Advisory Committee and RDN Staff, as well as two Public Information Meetings and ongoing consultation with the local community as part of the ZA and PDA process.

Through the extensive public consultation process, it is evident that the community strongly values the natural setting of the area and demands a high standard of environmental protection.

## 1.4 Project Team

This ISMP project was undertaken primarily by KWL with input from an inter-disciplinary team of professionals. The members and companies involved are outlined as follows:

**Table 2: Project Team**

| Firm | Team Members |
|---|---|
| Fairwinds Community & Resort | Russell Tibbles, Vice President, Development & Operations - Fairwinds, Bentall Kennedy<br>Dave Scott, Development Manager, Fairwinds Real Estate Management Inc. |
| Kerr Wood Leidal Associates | Crystal Campbell, Project Manager David Zabil, Technical Review<br>Jennifer Young, Aidan Hough, Craig Sutherland, Project Engineers<br>Rob Warren, Client Manager Jack Lau, GIS Specialist |
| Ekistics Town Planning | Paul Fenske, Principal / Urban Designer<br>Jeanette Elmore, Planner |
| Pottinger Gaherty Environmental | Susan Wilkins, Senior Biologist<br>Matt Hammond, Project Biologist |

Special thanks are also extended to Regional District of Nanaimo staff:

- Geoff Garbutt, General Manager of Strategic and Community Development
- Jeremy Holm, Manager, Current Planning
- Lainya Rowett, Senior Planner, Strategic and Community Development
- Maurice Mauch, Project Engineer, Engineering
- Mike Donnelly, Manager of Water and Utility Services
- Dan Huang, Senior Planner and Ehren Lee, Water Engineer, Urban Systems, Review for RDN.

# 2. Study Area Overview

Figure 2 shows an air photo of the Fairwinds area.

## 2.1 Topography and Soils

The topography is varied with hillsides, benches, terraces, lakes and lowlands. Figure 3 shows areas of gentle terrain (0 – 20% slopes, hillsides (20 – 40% slopes) and steep slopes (>40%).

### Soils

The surficial geology consists of upland soils compromised of glacial till soils, often with distinct lower layers that are a mixture of sand and crushed rock (from glaciation). Soil depth is generally thin veneers overlying bedrock with deeper deposits in the valleys, ravines and low lying areas (wetlands). Thick granular deposits were noted near the southwest shore of Enos Lake. Numerous bedrock outcrops were observed. Identified geotechnical hazards associated with potential slope stability and rockfall shall be mitigated at time of subdivision as per the recommendations of the *Preliminary Geotechnical Terrain Assessment.*[1]

## 2.2 Land Use

Existing land use within The Lakes District is mostly undeveloped and forested with some roads. Schooner Cove is partially developed with a decommissioned hotel, breakwater and marina.

The future Land Use Plan was created by using data collected early in the design process to describe the existing ecology on the site, and conducting a conservation planning exercise to overlay the spatial ecology information with community designs. This process enabled a design of specific areas to meet the dual objectives of:

(a) proposing a viable community design, and
(b) preserving the areas of highest environmental value.

As a result, the merits of this conservation planning approach have been continued throughout the planning process, from Neighbourhood Plan adoption through to drafting the Zone Amendments.

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[1] Summarized from *The Lakes District Neighbourhood Plan Background Summary, 2010* prepared by Ekistics Town Planning and *Preliminary Geotechnical Terrain Assessment for Proposed Subdivision, Fairwinds Neighbourhood 2, Nanoose Bay, B.C., 2008* prepared by Trow Associates.

By way of example, the Land Use Plan protects 85% of ESAs (including lakes, wetlands, streams and riparian areas) through park dedication, and a further 5% through protective covenants.

In implementing the Neighbourhood Plans for The Lakes District and Schooner Cove, Fairwinds is seeking to "balance the ecological, social, and economic needs of our future neighbourhood and community." A key component of the land use vision has been the use of environmentally responsible practices as identified in *Develop with Care: Environmental Guidelines for Urban and Rural Land Development in British Columbia* (MOE 2006) (see Sections 4.3 and 9.0).

Figure 4 shows the proposed land uses of the Neighbourhood Plans and they are described in Table 3.

**Table 3: Proposed Land Uses and Parameters**

| Land Use | Proposed Building Coverage [1] | Total Impervious Area[1] | Area (ha) | % of Area |
|---|---|---|---|---|
| **The Lakes District** | | | | |
| Regional Park | | 5% | 118.6 | 41.5% |
| Single Dwelling (800m$^2$, 400m$^2$ lots) | 40%, 60% | 50%, 70% | 68.2 | 23.9% |
| Duplex (750m$^2$, 600m$^2$ lots) | 65% | 75% | 46.4 | 16.2% |
| Road Right-of-Way | | 70% | 27.0 | 9.4% |
| Future Development Reserve | | 50% | 11.0 | 3.1% |
| Multiple Dwelling (3+ units) | 60% | 70% | 7.7 | 2.7% |
| Community Park | | 5% | 2.7 | 0.6% |
| Community Mixed Use | 70%, (80%*) | 80% (85%*) | 1.9 | 0.3% |
| Civic Infrastructure | | 80% | 1.4 | 0.3% |
| Lakehouse Community Mixed Use | | 80% | 1.9 | 0.3% |
| **Schooner Cove** | | | | |
| Multiple Dwelling | 70% (80%*) | 80% (85%*) | 3.4 | 33% |
| Village Mixed Use | 70% (80%*) | 80% (85%*) | 1.4 | 14% |

*where parking is fully underground
1. All data is based on the draft Comprehensive Development Zones for Lakes District and Schooner Cove

The existing total impervious area (TIA) of the Enos Creek watershed increases from 17% (297 ha total area) under pre-development conditions to 36% (310 ha total area) under post-development conditions. The Dolphin Lake watershed has a TIA of 22% (81 ha total area) under pre-development conditions and 43% (84 ha total area) under post-developed conditions. The catchment areas change slightly between pre- and post- development.

## 2.3 Existing Drainage

There are a number of existing water bodies within the study area or where the study area drains:

- Enos Lake and Dolphin Lake;
- twelve watercourses; and
- 12 wetland/ponds.

Refer to Figure 5. The coastal areas drain to Bluefin Bay and Schooner Cove within Georgia Strait.

Runoff from the proposed Lakes District development drains to three different water bodies:

- Enos Lake and downstream Enos Creek drains the majority of the study area.
- Dolphin Lake and downstream watercourse system drains a smaller portion of the study area.
- Stream S2 drains the northwest portion of the Lakes District.

The Schooner Cove study area drains directly to the marine environment in Schooner Cove. The southeast area drains to an existing storm drain system which is discharged to the marine environment in Dolphin Bay.

A field visit was undertaken on September 18, 2013 by Craig Sutherland, KWL and Dave Scott, Fairwinds to review the receiving watercourses/waterbodies and downstream external stormwater infrastructure. Their findings are summarized as follows and on Figure 5.

### Lakes

Enos Lake water levels are controlled by an outlet structure consisting of a culvert and stoplogs. The outlets for Dolphin Lake and Wetland W1 also have weir structures to control water levels. Dolphin Lake also has two siphons that convey water into the downstream creek. These lakes provide significant attenuation and reduction in downstream peak flow rates. There are also existing water licences for storage and irrigation for the Fairwinds Golf Course from these lakes.

**Table 4: Enos and Dolphin Lake Areas**

| Lake | Lake Area | Deepest Lake Depth | Catchment Area |
|---|---|---|---|
| Enos Lake | 18.2 ha | 12 m[1] | 249 ha |
| Dolphin Lake | 5.5 ha | 3 m | 81 ha |
| 1. Enos Lake is about 12m deep at its deepest point and is fairly shallow at both ends (1-2m) | | | |

**Enos Lake**

**Enos Lake Outlet Structure**

**Dolphin Lake**

**Dolphin Creek (S9)**

## Watercourses and Wetlands

Water body descriptions and photos were taken during the September 18, 2013 field visit as follows:

**Enos Wetland W1**. Some erosion of the cohesive clay/silt material downstream of the Enos Lake outlet culvert was observed. The Enos Wetland W1 is now more a meadow than a wetland since the beaver dam at the outlet was breached.

**Enos Creek (S1)**, flows out of Enos Lake and Enos Wetland W1. The creek is about 1.5 m to 2 m wide and flows through a well-defined bedrock gully. Significant wood debris is in the channel, which most likely remains from a beaver dam breach about 13 years ago. The stream downstream of the beaver dam shows signs of erosion.

**Enos Creek (S1) at Swallow Rd and Dolphin Drive looking upstream at 1,500 mm dia**

Downstream of the Fairwinds property, the creek flows through a low gradient stream which backs existing single family properties. This portion of the creek was not observed during the site visit; however, it is understood that the stream flows through a series of small wetland areas before flowing into the culverts under Swallow Crescent and Dolphin Drive. Downstream of Dolphin Drive, the creek flows over a 3 m high waterfall before flowing into Georgia Straight at Dolphin Beach. This waterfall poses a barrier to fish passage.

**Stream S2** drains from the north-west corner of the study area. This stream flows overland through the property at 2940 Dolphin Drive before flowing into a 900 mm diameter storm drain, which parallels Dolphin Drive, to a manhole in front of 2930 Dolphin Drive where it turns 90$^{o}$ and crosses under Dolphin Drive before passing through the property at 2949 Dolphin Drive to the ocean.

Several small tributary streams flow into Enos Lake, identified as S3 to S7 on Figure 5. It is likely that they all run dry during summer.

**Wetland W2 on Stream S3**

**Stream S3** flows out of **Wetland W2** on the south-west side of Enos Lake. This wetland is located high on a bedrock ridge above the lake. The pond was formed when peat was excavated from the area and the water level has been raised about 0.5 m by a beaver dam at the outlet. There were no signs of recent beaver activity or active erosion or instability of the dam. The stream flowing out of the wetland flows over an exposed bedrock meadow and over a cliff into the lake.

**Wetland W4** is the largest in the study area and has three or four inactive beaver dams at the outlet. The beaver dams form a series of smaller ponds. The water level difference across each of the beaver dams is about 0.3 m to 0.5 m, with a total elevation drop between the lowest and upper pond estimated to be about 1.0 m. The dams are well vegetated with no signs of significant active erosion of the dams. However, the stability of the dams is difficult to assess due thick vegetation cover and limited access to the ponds.

**Wetland W5** is located on the western edge of the study area and the water levels have been raised about 0.5 m by beaver activity. No active signs of beaver activity were observed and there was no apparent outlet from the pond. However, Mr. Dave Scott reports that the wetland outflows near the northwest corner of the wetland and flows down the roadside ditch adjacent to Florence Drive and is directed down the existing trail to wetland W4.

**Stream S6 near Outlet to Lake**

**Stream S6** flows out of Wetland W4 and outlets over a 5 m high bedrock waterfall to Enos Lake. It is approximately 1 m wide and about 0.5 m deep and flows down a well-defined bedrock valley. The banks of the channel are cut into cohesive clay and glacial till soils and appear to be resistant to erosion. The banks are well vegetated, except where the stream flows through cedar groves.

**Stream S7** flows from the lower slopes of Nanoose Hill to Enos Lake. It passes through a 900 mm culvert under Fairwinds Drive before flowing down a steep embankment to the lake.

**Wetland W7** flows into Enos Lake. No erosion or stability concerns were observed. There are existing stormwater detention ponds located upstream (south) of Wetland W7.

**Wetland W7 located at upstream end of Enos Lake**

**Existing stormwater detention ponds south of Fairwinds Drive**

**Stream S9**, downstream of Dolphin Lake, is a highly modified stream with detention ponds through the Fairwinds Golf Course and a storm drain outfall to the ocean.

Wetland areas are summarized as follows:

**Table 5: Wetland Areas**

| Wetland ID | Area ($m^2$) | Wetland ID | Area ($m^2$) |
|---|---|---|---|
| W1 | 13,062 | W5 | 8,166 |
| W2 | 9,954 | W6 | 770 |
| W3 | 794 | W7 | 8,390 |
| W4 | 25,083 | W8 | 357 |
| | | W9 | 4,555 |
| Shading represents largest wetlands .>1 ha), mid-sized wetlands (>0.4 ha) | | | |

### Schooner Cove

The Schooner Cove area drains to Georgia Strait. As shown on Figure 5, the area is divided into three catchments (North, South, and East). The Northern and Eastern Catchments drain directly to the ocean and the erosion impact, if any, is extremely limited and is not a concern. The Southern Catchment drains through an existing culvert and onto a beach and then the ocean. Erosion was observed between the end of the culvert and the head of the beach.

### Existing Drainage Problems

No existing drainage problems were noted by Dave Scott, Fairwinds or Encon, MOTI contractor.

## 2.4 Existing Erosion Sites

Erosion sites are noted on Figure 5:

- Enos Creek (Stream S1) downstream of the beaver dam.
- Schooner Cove Southern Catchment on the beach between the end of the culvert and the head of the beach.

Stream S7 bank riprap downstream of Fairwinds Drive culvert is marginally stable and should be monitored.

## 2.5 Environmental Values

The Lakes District is home to a number of high-value environmental features including steep hillsides, environmentally sensitive forest areas and wetlands providing unique habitat for waterfowl, wildlife and other fauna. The key environmental findings are shown on Figure 6.

## Aquatic Resources

The water bodies and watercourses within the study area include:

- Enos Lake and Dolphin Lake.
- Twelve watercourses labelled S1 to S12 on Figure 6.
    - Two primary (>3rd order) watercourses – S1 Enos Creek and S9 Dolphin Creek;
    - Seven smaller 1st order watercourses S2 to S8; and
    - Three streams connecting water bodies S10 to S12.

  All the watercourses meet the minimum length of 100 m continuous channel and are classified as streams under the Riparian Areas Regulation. [2]
- Nine wetlands.

### Aquatic Species & Habitat

There are Stickleback in Enos Lake and Enos Creek. All the other watercourses are considered non-fish bearing as a result of the steep topography and numerous fish barriers. However the lower reaches of watercourses S3 to S8, draining into Enos Lake, are considered fish stream habitat. Dolphin Lake is much shallower and smaller than Enos Lake and has lower habitat values.

### Stickleback in Enos Lake and Enos Creek

Historically, Enos Lake has been habitat for a unique and at risk species of small fish, the Stickleback Species Pairs, and/or a hybridized version of the pairs which presumably require similar conditions to the original. The current situation and recovery strategy is described in the Species at Risk Act (SARA) report[3]. This report states that the Enos Lake species pair has collapsed into a single hybrid swarm. Regardless, one of the long-term goals is to, "*establish or recover a viable population of the Enos Lake species pair, preferably in Enos Lake*".

The Enos Lake species pair collapsed due to hybridization (Kraak et al. 2001; Taylor et al. 2006), and the appearance of the American Signal Crayfish in the 1990s is implicated. The mechanism by which the crayfish affected sticklebacks appears to be through littoral habitat disturbance and alteration (Rosenfeld et al. 2008), although differential impacts on limnetic breeding success are also a plausible mechanism (Velema 2010).

### Special Requirements for Enos Lake/Creek Stickleback

The SARA report states that, "*As a group, sticklebacks are tolerant of a fairly large range of water quality conditions. The current provincial water quality standards for the protection of aquatic life are appropriate guidelines for basic parameters of water quality in lakes with stickleback species pairs. However, some aspects of water quality in species pair lakes need to be maintained in a much narrower range than that required for short-term individual survival, as described below.*" The report continues and identifies the following water quality aspects:

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[2] Detailed Biophysical Assessment, Cascadia Biological Services, February 2009

[3] Recovery Strategy for Paxton Lake, Enos Lake, and Varanda Creek Stickleback Species Pairs in Canada, Fisheries and Oceans Canada, July 2007.

- Light Transmission – suspended solids, dissolved organic carbon, others affecting light transmission;
- Nutrients – nitrogen, phosphorus, total alkalinity;
- Extent of Littoral Habitat (part of the lake or stream that is close to the shore - extends from the high water mark, which is rarely inundated, to shoreline areas that are permanently submerged); and
- Extent of Macrophyte Beds (aquatic plant that grows in or near water and is either emergent, submergent, or floating. They provide cover for fish and substrate for aquatic invertebrates, produce oxygen, and act as food).

Enos Lake/Creek Stickleback Management Measures:

- The nutrient levels in the Lake should be monitored and the use of fertilizers within the watershed may have to be controlled or eliminated.
- The littoral habitat and macrophyte beds shall be protected by limiting access points to the lake and protecting those areas which are the most productive for the Stickleback. There are reports that the current state of macrophyte beds has been adversely impacted by the presence of non-native crayfish.

## Vegetation and Habitat Zones

The study areas lie within the Moist Maritime subzone of the Coastal Douglas Fir zone, which occurs along a small portion of south-eastern Vancouver Island, several islands in the Georgia Strait and a narrow strip of mainland British Columbia. It is characterized by warm, dry summers and mild, wet winters. Forests are dominated by Douglas-fir, and are accompanied frequently by western red cedar, grand fir, arbutus, Garry oak and red alder.

Understory species include salal, dull Oregon-grape, ocean-spray, bracken fern, sword fern, trailing blackberry, western trumpet honeysuckle and Oregon beaked moss.

The Neighbourhood Plan identifies seven Garry oak ecosystem polygons, with total extents of approximately 15 hectares (37 acres). Within the local context of Nanaimo/Nanoose, this area represents approximately 5% of the remaining coverage of this ecosystem type. The area lies within the northernmost tip of the native range of Garry oak, which extends from Vancouver Island to southern California. This sensitive habitat hosts a mix of vegetation consisting primarily of Garry oak and Arbutus, ocean-spray and common camas, along with a dense layer of rock moss and lichens. The Garry oak ecosystem provides habitat for a wide variety of wildflowers and grasses.[4]

### Riparian Forest Cover

Riparian areas, surrounding watercourses, lakes and wetlands, are largely intact and consist of red alder, big-leaf maple, Douglas fir, and many other riparian ecosystem plants. Figure 6 shows 15 m setbacks for wetlands and watercourses and 15 to approximately 30 m setbacks for Enos Lake.

[4] The Lakes District Neighbourhood Plan Background Summary, Ekistics, December 2010.

### Wildlife

Typical of the rural, forested landscapes of Nanoose Peninsula, terrestrial wildlife habitat in the Lakes District Neighbourhood Plan area is largely defined by second-growth forest, wetlands and lakes, and a variety of large mammals (including cougar and black-tailed deer), small mammals (including raccoon, beaver, river otter, grey and red squirrels), bird species (including bald eagle and red-tailed hawk), reptiles (including lizards and snakes) and amphibians (including frogs and newts).[5]

## 2.6 Enos Lake Water Quality Data

Water quality sampling has been undertaken bi-annually on Enos Lake since 2006. AquaTerra Environmental has provided a comprehensive summary of the water quality measurements taken since 2008. Their latest 2013 Water Quality Report can be found in Appendix B.

In general, since 2006, Enos Lake water quality parameters have remained relatively stable for such indicators as Total Suspended Solids (TSS), pH, Dissolved Oxygen, total Nitrogen and total Phosphorus concentrations remaining within the range of historically measured values. In addition, dissolved metal concentrations have been consistently below the available BC Water Quality Guidelines for the Protection of Aquatic Life. The table below summarizes the average measured values between September 2006 and March 2013.

**Table 6: Average Water Quality Values Sept 2006 - March 2013**

| Parameter | Units | Average Measured Values | Parameter | Units | Average Measured Values |
|---|---|---|---|---|---|
| pH | pH | 7.85 | Dissolved Fluoride | ug/L | 37.97 |
| Dissolved Oxygen | mg/l | 11.58 | Dissolved Chloride | mg/L | 12.29 |
| Total Suspended Solids | mg/L | 3.51 | Dissolved Nitrate | mg/L | 0.03 |
| Turbidity | NTU | 7.06 | Dissolved Sulphate | mg/L | 4.89 |
| Hardness $CaCO_3$ | mg/L | 50.13 | Ammonia Nitrogen | mg/L | 0.03 |
| Total Carbon | mg/L | 15.92 | Nitrate and Nitrite | mg/L | 0.02 |
| Total Organic Carbon | mg/L | 5.85 | Total Kjeldahl Nitrogen | mg/L | 0.41 |
| True Colour | CU | 10.72 | Total Organic Nitrogen | mg/L | 0.38 |
| Total Suspended Solids | mg/L | 2.09 | Total Nitrogen | mg/L | 0.42 |
| Turbidity | NTU | 1.63 | Total Phosphorus | mg/L | 0.02 |
| Dissolved Manganese | ug/L | 14.90 | Trophic State Index (Chlorophyll A) | | 49.21 |

Two of the parameters should be noted due to their importance in identifying the overall health of the lake; specifically Manganese and Chlorophyll A.

[5] The Lakes District Neighbourhood Plan Background Summary, Ekistics, December 2010.

Manganese in the lake is generally a result of stormwater runoff and atmospheric deposition. However, a decrease in the manganese concentrations may indicate a recovery, if recently culled, or boom in the Signal Crayfish population within the lake. Numerous studies have shown that there is a high rate of manganese uptake by crayfish, which accumulates within their soft tissue and is subsequently released during decomposition.

Chlorophyll A is used as an indicator of trophic (aquatic food chain) health by way of the Trophic State Index (TSI). TSI is a standardized method for determining the lake nutrient conditions (Carlson 1977). In general, a TSI of less than 30 with a dissolved oxygen concentration of greater than 9.5 mg/l indicates a suitable habitat for salmonoids. TSI levels between 30-70 indicate the potential presence of an oxygen poor layer of water in a stratified (non-recirculating) lake in summer and a suitable environment for warm water fish such as the Stickleback. Levels in excess of 70, indicate that the lake's natural biologic function may be compromised.

The highest calculated TSI was 59.9 in spring 2009 followed by 32.6 (Fall 2010), 52.5 (Fall 2011) and 31.8 (Summer 2012). Based on these highly variable TSI results, it is anticipated that external factors have an overriding influence on the Lake's trophic state (AquaTerra, 2013).

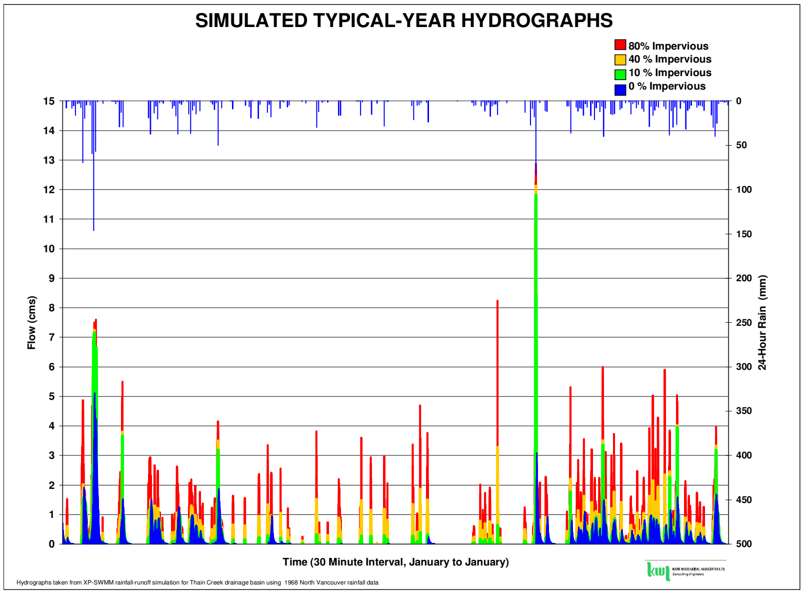
# 3. Stormwater Management

## 3.1 Typical Stormwater Impacts of Land Development

Land development typically involves replacing pervious forested area with impervious pavement, concrete and building structures. Redevelopment typically involves replacing developed areas with higher density land use with a further increase in total impervious area. Increasing impervious area results in two types of impacts:

- **Stormwater Quantity Impacts:** Increased and faster responding peak flow rates. During extreme rainfall-runoff events this can cause flooding and erosion, and during typical rainfall events this can cause watercourse erosion and instability and deteriorate aquatic habitat. There is less infiltration into the ground which can decrease baseflows during dry weather periods and therefore reduce the fish support capacity of a watercourse.
- **Stormwater Quality Impacts:** Land development and building construction activities result in sedimentation of watercourses. It has been found that urbanization over 30% TIA also results in non-point source (NPS) pollution of receiving waters and poor stream water quality. Together, sediment and contaminants can significantly degrade the fisheries value of a creek system.

Prior to land development, minor rainfall events do not yield surface runoff. However, because of increased impermeable area, surface runoff from these minor storms is produced after land development. This is clearly shown in the typical-year hydrograph for various levels of development.




**Simulated Typical-Event Hydrograph for Levels of Imperviousness**

Research has shown that urban development, which typically increases impervious area and decreases riparian corridor, significantly impacts stream bank stability, the abundance and diversity of fish populations and benthic macroinvertebrate (insects in the stream bed) communities.

## Primary Factors Limiting the Ecological Health of Urban Waterways

Research on urban streams indicates that four primary factors affect ecological health. They are listed, in order of importance, as follows:

- changes in hydrology;
- disturbance to the riparian corridor;
- disturbances to fish habitat; and
- deterioration in water quality.

'Changes in hydrology' can be viewed as the paramount factor because it can impact the other factors. Increases in hydrology (flows and volumes and the frequency of their occurrence) accelerates natural rates of erosion and sedimentation, degrades or washes out aquatic and riparian habitat, and deteriorates water quality.

By the time pollutant loading is a significant water quality problem affecting fish survivability, the higher frequency of occurrence of increased flows resulting from land use densification have already degraded or disturbed the physical features associated with productive fish habitat.

Understanding the four limiting factors is key to developing guiding principles for an integrated approach to the environmental component of the ISMP. ISMPs strive to mitigate the hydrologic impacts of development through stormwater management measures such as source controls for volume reduction and water quality treatment and detention facilities for flow rate control.

## 3.2 Stormwater Design Event Modelling

A SWMM hydrologic and hydraulic model was developed to estimate existing and future unmitigated flows and lake levels to assess the impacts of the proposed development. Figure 7 shows the pre- and post-development catchments. The SCS Type 1A design storm distribution used which is applicable to the west coast and recommended by MOTI[6]. Design rainfall depths were obtained from the Nanaimo City Yard AES Station IDF curve.

**Table 7: Nanaimo City Yard Rainfall Depths**

| Duration (hours) | Return period (years) | | |
|---|---|---|---|
| | 2-year | 10-year | 100-year |
| 24 | 58.0 | 83.3 | 115.0 |

The PC SWMM infiltration and groundwater routines were used to model the interflow in the shallow soil layer (100 mm thick). Impervious percentages were assigned based on the air photo with undisturbed areas assumed to be 5% impervious to account for any bedrock outcrops. The lakes were modelled as impervious areas to simulate zero infiltration and 100% runoff. In the post-development model, the impervious values associated with the various land uses (Table 3) were used and it was assumed that topsoil would be imported onto pervious disturbed areas resulting in a 300 mm topsoil thickness in irrigated areas. The hydraulics layer in PC SWMM was used to simulate the lake storage and outlets. The peak flow estimates at key locations in the watershed are summarized in Table 8.

## 3.3 Impact to Enos and Dolphin Lakes

A water balance calculation was developed to assess the impact of future development on the Enos and Dolphin Lakes typical water levels. A continuous simulation was undertaken using 9 years (2002 to 2010) of daily rainfall from the *Nanaimo City Yard* AES climate station, scaled down by approximately 20% to represent Fairwinds rainfall levels. Nanaimo (23 year period of record) has an annual average rainfall of 1141 mm compared with Fairwinds (22 year period of record) with 913 mm (from their records). The model results were validated with recorded monthly water levels to yield a good fit as shown Figure 8. A more detailed description of the modelling and its results are included in Appendix A, Section A.3.

The water balance calculation predicted continuous pre- and post-development water levels over the 9 year period of record for both Enos and Dolphin Lakes shown in Figures 9 and 10 respectively. Post-development water levels are generally higher than the pre-development levels, up to 7 cm higher in both lakes and have an overall minimal impact. Higher water levels would occur for a very short period of time.

The Environmental Impact Assessment indicated that a 7 cm raise is within the natural range of lake level variability so does not pose a habitat concern, particularly in a largely steep-sided lake.[7]

[6] MOTI 2007 *BC MoT Supplement to TAC Geometric Design Guide, Section 1000, Hydraulics Chapter*

[7] Environmental Impact Assessment – Pottinger Gaherty Environmental, 2010.

**Table 8: Peak Flow Estimates for Pre-development and Post-development Land Uses**

| Location | | Pre-Dev | | Post-Dev | | % Diff TIA | 2-Year Flows (m3/s)[3] | | | 10-Year Flows (m3/s) | | | 100-Year Flows (m3/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Area (ha) | TIA | Area[1] (ha) | TIA[2] | | Pre-Dev | Post-Dev[4] | % Diff | Pre-Dev | Post-Dev[4] | % Diff | Pre-Dev | Post-Dev[4] | % Diff |
| Enos Lake | Stream S6 Catchment | 87 | 20% | 84 | 33% | 65% | 0.79 | 1.35 | 71% | 1.10 | 2.80 | 155% | 2.13 | 4.06 | 91% |
| Enos Lake | Stream S4 Catchment | 10 | 5% | 8 | 61% | 1120% | 0.10 | 0.16 | 60% | 0.10 | 0.28 | 180% | 0.24 | 0.4 | 67% |
| Enos Lake | Enos Lake Outfall | 249 | 16% | 259 | 33% | 106% | 0.30 | 0.33 | 10% | 0.73 | 0.78 | 7% | 1.34 | 1.49 | 11% |
| Enos Creek Outfall | | 297 | 23% | 310 | 42% | 83% | 0.56 | 0.92 | 64% | 1.02 | 1.61 | 58% | 1.59 | 2.33 | 47% |
| Dolphin Lake Outfall | | 81 | 22% | 84 | 43% | 95% | 0.54 | 0.53 | -2% | 0.69 | 0.94 | 36% | 1.15 | 1.93 | 68% |

1. Catchment areas changed slightly between pre- and post-development
2. TIA = % Total Impervious Area, assumes wetland areas are impervious, but do not include lake areas. In models lakes were considered impervious area.
3. Flow estimates at hourly average peak flows
4. Post-Dev = Unmitigated post-development flow. Proposed capture source controls and detention facilities will reduce peak flows.

**>100% increase**
**>50% increase**
**>25% increase**

Q:\2900-2999\2964-002\300-Report\20131119_Final Report\[Table8 Flow Estimates.xls]Sheet1

### Impact of Water Licence Withdrawals on Enos Lake Water Levels

There are two existing water licenses for withdrawal from Enos Lake. One is an active withdrawal license for 173,000 $m^3$/year (140 acre-feet per year), and the second is a pending withdrawal license for 185,000 $m^3$/year. It is estimated that currently approximately 96,000 $m^3$ of water is withdrawn from Enos Lake per year (based on 2009 water use estimate). This estimate is based on limited recorded use information and could be refined in the future by keeping records of the pumped volumes.

It is estimated that the current withdrawals are approximately 56% of that allowed by the active water license. If the full active license amount of 173,000 $m^3$/yr were to be withdrawn every year over a three month period (mid June to mid September), the drawdown in Enos Lake would lower the minimum lake levels by approximately 0.4 m, compared to current minimum water levels.

## 3.4 Potential Stormwater Impacts of Fairwinds Future Development

The potential impacts associated with the Fairwinds Development are outlined in Table 9, together with the need for and suggested mitigation measures.

## 3.5 Drainage System - Provide Safe Conveyance of Flood Flows

The proposed drainage system is shown in Figure 11 consisting of:

- Grading that drains on-lot impervious runoff toward road/municipal right-of-ways;
- Storm sewers for minor drainage system;
- Roads, existing watercourses, culvert, bridges for major drainage system;
- Outfalls; and
- Cutoff ditches to direct undeveloped upslope area flows away from development.

The overall drainage system and flow paths are shown on Figure 11. The storm sewers are colour coded to reflect the type of treatments required based on receiving water. For example, a majority of the storm sewers discharge directly to the lakes (dark blue) and therefore this area requires water quality treatment, but not water quantity control because the lakes can accommodate the increased peaks. The storm sewers shown in red discharge to existing wetlands and also require water quality treatment, but not quantity control. Several storm sewers discharge directly into streams (light blue) and therefore outflows require both water quality treatment and peak flow attenuation or creek bank protection measures to minimize erosion. Lastly, the storm sewers shown in green discharge to existing storm sewers and require water quality treatment and a capacity assessment of the existing storm sewer to assess if the post-development flows can be accommodated (next Section 3.6). Water quality treatment and detention measures are discussed in Section 3.7.

**Table 9: Potential Stormwater Impacts with Fairwinds Development**

| Impact | Relevancy | Recommend Mitigation Measures |
|---|---|---|
| **The Lakes District** | | |
| Increased runoff peak flows & volumes | ➔ For extreme events.<br>➔ Need for safe flood conveyance system through proposed development area & downstream drainage areas. | Minor drainage system - storm sewers, culverts, ditches<br>Major drainage system – overland flow on roadways, culverts, streams |
| | ➔ For frequently occurring events.<br>➔ Mitigate impacts for areas draining to erodible watercourses or provide erosion protection. | Need volume reduction and detention measures – bioretention facilities, detention/diversion facilities to minimize erosion or provide bank protection. |
| | ➔ Minimal impact to wetland water levels | Erosion protection at storm sewer outlets.<br>Preserve tributary areas/flows to wetlands. |
| | ➔ Minimal impact to lake water levels – see Sub-section 3.3 | Possible modifications to lake outlets. |
| Decreased runoff water quality | ➔ Need water quality treatment facilities prior to discharge to water bodies – wetlands, streams, Enos Lake, Dolphin Lake, Georgia Strait | Roadside rain gardens, regional biofiltration facilities or wetlands. |
| Decreased groundwater recharge & stream baseflows | ➔ Need infiltrating source controls on permanent watercourses | Disconnected roof leaders for lots adjacent and upslope to natural areas, roadside rain gardens, regional biofiltration facilities or wetlands. |
| Realignment small ephemeral creeks | ➔Realignment of portions of S4 & S8 | Dedicated park lands and rain gardens & rainwater creeks. |
| **Schooner Cove** | | |
| Increased runoff peak flows & volumes | ➔ Need for safe flood conveyance system through proposed development area | Site grading, storm sewer /swales. |
| | ➔ Need to mitigate erosion | Storm outfall erosion protection. |
| | ➔ No impact to Georgia Strait water levels and no watercourses. | No detention required. |
| Decreased runoff water quality | ➔ Need water quality treatment prior to discharge to Georgia Strait | Oil/grit separators. |
| Decreased groundwater recharge & stream baseflows | ➔ N/A because adjacent to shoreline. | N/A |

## 3.6 Impact to Downstream Drainage System

The proposed development drainage enters existing downstream infrastructure at 15 locations shown on Figure 12. The capacities of the existing storm sewers and culverts were determined and assessed as to whether upgrades will be required to convey the post-development flows. The locations of the assessed pipes are shown in Figure 12 and the assessment results are presented as follows.

**Table 10: Existing Pipe Capacity Assessment**

| Pipe ID | Pipe Size and Slope (assumed info) | Existing Pipe Capacity ($m^3/s$) | Future Peak Flows ($m^3/s$) | Upgrade Pipe Size[1] |
|---|---|---|---|---|
| **Culverts** | | **(100-Year)** | | |
| 3 | 900 ø conc @1% | 1.8 | 1.47 | n/a |
| 4 | 1500 ø csp @1% | 3.8 | 2.27 | n/a |
| 5 | 1750 ø csp @1% | 5.8 | 2.27 | n/a |
| 7 | 900 ø csp @1% | 0.98 | 0.9 | n/a |
| 13 | 1250 ø csp @1% | 2.4 | 1.11 | n/a |
| 14 | 375 ø conc @ 5.6% | 0.41 | 0.12 | n/a |
| **Storm Sewers** | | **(10-Year)** | | |
| 1 | 900 ø csp @1% | 0.98 | 0.92 | n/a |
| 2 | Unknown | unknown | 0.51 | 750[1] |
| 6 | 600 ø conc @1% | 0.61 | 0.03 | n/a |
| 8 | 300 ø conc @6% | 0.24 | 0.05 | n/a |
| 9 | 375 ø conc @6% | 0.43 | 0.05 | n/a |
| 10 | 600 ø conc @7.6% | 1.7 | 0.33 | n/a |
| 11 | 750 ø conc @5.5% | 2.6 | 0.53 | n/a |
| 12 | 450 ø conc @1% | 0.28 | 0.27 | n/a |
| 15 | 900 ø csp @1% | 0.98 | 0.27 | n/a |
| 1. Confirm assumed information and capacities prior to upgrading. | | | | |

Downstream infrastructure can convey the proposed development peak flows, no upgrades are required.

### Climate Change Sensitivity Analysis

Impacts of potential climate change on the downstream infrastructure were examined. The current climate change predictions show a 10% to 20% increase in precipitation by Year 2080 (Metro Vancouver report, *Vulnerability of Vancouver Sewerage Area Infrastructure to Climate Change* (March, 2008)). It can be assumed that during large rainfall events with wet antecedent conditions, an increase in precipitation will result in a similar increase in peak flow. Therefore, as an indicative assessment of climate change impacts on downstream infrastructure, the peak flows in Table 10 above were increased by 10% and 20% to determine whether any additional pipe capacities would be exceeded.

With 10% larger flows, none of the pipe capacities are exceeded. With 20% larger flows, Storm Sewers #1 and #12 and Culvert #7 would be approximately 10% over capacity. Storm sewer exceedances will result in additional flow on the roads and/or overland flow paths and may be acceptable. Exceedances of culverts may be accommodated with surcharging at the inlet, or may result in road overtopping. This can be assessed at subdivision design when more survey information is available.

This sensitivity analysis can be performed on the proposed stormwater infrastructure (storm sewer and overland flow) system when sized during subdivision design to determine the risk and consequences of flooding and impact to sizing.

## 3.7 Conservation Measures

### Conserve Creeks, Wetlands and Riparian Areas

All creeks are maintained within the proposed development plan with the exception of insignificant ephemeral watercourses S4 and part of S8 discussed in the next subsection. Maintaining watershed health requires the preservation and conservation of wetland and riparian areas. All wetland areas are preserved and riparian setbacks are shown on Figure 6 and proposed as follows:

**Table 11: Proposed Riparian Setbacks**

| Water Body | Proposed Setback |
|---|---|
| Enos Creek (S1) and Enos Lake | 15 - 30 m |
| Ephemeral watercourses (S2 – S8) | 15 m |
| Wetlands (W1 – W9) | 15 m |
| Detailed RAR assessments are required. | |

### Re-orient Insignificant Ephemeral Watercourses

**Watercourses S4 and S8** are non-fish-bearing, but provide flow (likely only during wet months) and nutrients to Enos Lake. The Neighbourhood Plan proposes to re-orient these small (<1m width) creeks into vegetated corridors, if necessary, that is part of the protected greenspace network and/or restrictive covenants on specific properties. The redesign of these streams should involve the advice of an aquatic biologist to ensure that current function is maintained post-development. The watercourses outlets remain the same and there is no-net-loss of aquatic habitat.[8]

### Conserve Environmentally Sensitive Areas

The Neighbourhood Plan conserves much of the environmentally sensitive areas through regional park dedications as shown on Figures 4 and 6.

[8] Environmental Impact Assessment – Pottinger Gaherty Environmental, 2010. P4

## 3.8 Stormwater Mitigation Measures to Maintain Watershed Health

### Guiding Principles for Fairwinds Stormwater Management

The following guiding principles were used in developing the Fairwind stormwater management approach:

a. Provide water quality treatment prior to discharge to all receiving waters – ocean, lakes, streams, wetlands.

b. Maximize water quality treatment source controls - Implement roadside rain gardens on all roads less than 10% slope.

c. Use regional water quality treatment facilities only where regional detention facilities are also required so they can be combined facilities.

d. Divert post-development flows to lake instead of streams where possible to minimize detention facilities required. Implement flow splitters to direct baseflows and low flows to streams to maintain source of food to aquatic life in lake.

### Water Quality Treatment Measures to Protect Wetland/Lake/Ocean Water Quality

Stormwater runoff from roads and paved surfaces exposed to vehicle traffic require water quality treatment to maintain good water quality in receiving water bodies – creeks, wetlands, lakes, and ocean. The following measures are proposed:

- Roadside vegetated swales (rain gardens and/or grassed swales) to treat road runoff. Locations of roads with swales and a typical cross-section are shown on Figure 13.
- Regional wetlands where detention is also required (Combined treatment/detention facilities).
- Rainwater creeks or piped outfalls with energy dissipaters to Enos Lake to aerate the incoming flows to improved low dissolved oxygen levels.

Refer to Figure 13.

**Continuous Simulation Modelling for Rain Garden Sizing**

Continuous simulation modelling was also performed using KWL's water balance spreadsheet to size water quality treatment best management practices (BMPs). Nine years (2002 to 2010) of daily rainfall from the *Nanaimo City Yard* AES climate station, scaled down by approximately 20% to represent Fairwinds rainfall levels was used. Nanaimo (23 year period of record) has an annual average rainfall of 1,141 mm compared with Fairwinds (22 year period of record) with 913 mm (from their records).

Roadside rain gardens were sized to treat 90% of the annual rainfall volume by filtering the road runoff through the rain garden topsoil layer. The impervious to pervious area ratio (IP ratio) of the rain garden was also checked to prevent overloading of the rain garden with sediment. Through observations of constructed swales and rain gardens it was found that a maximum IP ratio of 40:1 is required for local roads.

The water balance and IP ratio limits indicated that a rain garden surface area of 250 $m^2$ per hectare of tributary impervious area is required. The maximum impervious width in any of the six road types proposed in the Ekistics 2012 *Project Specific Street Standards* for road cross sections is 11.2 m. Refer to Figure 14 Minor Collection 50 kph Cross Section with Drainage Configuration. The road cross sections all have a minimum 2.4 m wide allowance for the rain garden. Given a 0.3 m rain garden depth, 2H:1V side slopes, and a 0.5 m wide shoulder next to the curb, the bottom width of the rain garden may be up to 0.7 m wide (2.4 m – 0.5 m – 2x0.3 m – 2x0.3 m = 0.7 m). To achieve the 250 $m^2$ per hectare of impervious area would mean that breaks in the rain garden (driveways) must cover no more than 60% of length of road flowing into it (100% – (11.2 m / 0.7 m x 250/10,000) x 100%) or 40% of the lineal road length requires rain gardens.

**Stormwater Pollutants and Rain Garden Removal Efficiencies**

Stormwater runoff pollution increases with increased impervious area. Typical urban pollutants that can be expected in stormwater are:

- **Suspended solids** (turbidity) that lower dissolved oxygen and clog fish gills and spawning habitats, wetlands, etc.
- **De-icing salts and sand** during winter months. Salts can inhibit vegetation growth; impact wildlife, birds, and aquatic biota; and corrode motor vehicles and infrastructure. De-icing chemicals can also accumulate in road side snowpacks and be released in pulses during snowmelt.
- **Heavy metals** (lead, zinc, copper, cadmium, mercury, iron, nickel) from motor vehicle operation.
- **Oil, grease, and hydrocarbons** can be expected from highways and parking lots.
- **Chemical oxygen demand (COD)** is the oxygen consumed by oxidation (by biological or chemical means) of organic matter in solution. It lowers dissolved oxygen and can adversely affect aquatic life.
- **Nutrients** such as nitrogen and phosphorus can deteriorate water quality by eutrophication.

General sources of stormwater pollutants originate primarily from the accumulation and wash-off of solids and other pollutants from impervious urban surfaces. These solids and pollutants come from automobile traffic/accidents (leakage, particles, dirt, rust, etc.), construction activities, animal waste, leaking sanitary sewers, sanitary cross-connections, corrosion of metallic surfaces (roofs), litter, dumping, and atmospheric deposition.

Numerous papers and publications were reviewed for data on rain garden pollutant removal. Researchers have studied rain garden performance for the last 20 years, but the results are sometimes conflicting, the methodologies inconsistent, and more research is needed to better define the parameters of rain garden design and how they influence the performance results. A list of the publications reviewed may be found under References at the end of this report. Typical pollutant removal rates are summarized in Table 12.

The water quality treatment criterion is to remove 80% of Total Suspended Solid based on 50 µm particle size from 6-month 24-hour storm (72% of the 2-year 24-hour storm). Well designed and constructed rain gardens can achieve this.

**Table 12: Rain Garden Typical Pollutant Removal Efficiencies**

| Pollutant | Low End of Range | High End of Range |
|---|---|---|
| TSS | 15% | 90% |
| Bacteria - both E.Coli and FCC | 37% | 95% |
| Hydrocarbons | 62% | 98% |
| Copper | 43% | 97% |
| Lead | 70% | 95% |
| Zinc | 64% | 95% |
| Phosphorus | 65% | 87% |
| Total Kjeldahl Nitrogen (TKN) | 52% | 67% |
| Ammonium (NH4+) | N/A | 92% |
| Nitrate (NO3-) | 15% | 16% |
| Total nitrogen | N/A | 49% |
| Calcium | N/A | 27% |

## Runoff Volume Reduction/Rate Control Measures to Minimize Stream Erosion

Enos and Dolphin Lakes can accommodate the estimated stormwater quantity impacts associated with the proposed development. Outlet modifications should be assessed in a more detailed functional feasibility study.

Areas discharging to watercourses will require mitigation measures to minimize erosion, such as:

- Reducing flow volumes and rates to pre-development conditions, such as 1. bio-retention and detention or 2. Diversion of excess flows to lake/ocean.
- Creek bank armouring - because all but one of the creeks are not fish bearing and are located on bedrock, providing bank protection works such as bio-stabilization on flatter sections and riprap in steeper sections would minimize future erosion.

Because areas draining to watercourses will require these types of additional measures, the drainage plan strives to minimize post-development areas draining to watercourses.

A number of best management practices options were considered for each catchment shown on Figure 13. These options are explored and qualitatively evaluated in Table 13. The following volume reduction/rate control measures are proposed:

- Roadside swales for road runoff.
- 300 mm absorbent topsoil on landscaped and irrigated areas.
- Disconnected roof leaders for lots adjacent, and upslope, to natural areas.
- Regional treatment/detention facilities for areas that require it. See Figure 13.

**Table 13: Stormwater Best Management Practice Options and Recommendations**

| Receiving Water | Catchment / Wetland | Stormwater Requirement | Stormwater BMP Options | Recommended BMP (Refer to Figures 13 & 16) |
|---|---|---|---|---|
| Ocean | Schooner Cove | WQ only | **Bio-filtration Source Controls**<br>Bio-filtration Regional Facility<br>Enhanced oil/grit separator | • Roadside and parking lot rain gardens |
| Ocean | Pipe West of S2 | WQ only | **Bio-filtration Source Controls** | • Roadside rain gardens |
| Ocean | Stream S2 | WQ | **Bio-filtration Source Controls** | • Roadside rain gardens |
| | | Volume ↓<br>Rate Control | **Armour Creek Banks,** Detention<br>Diversion | • Armour Creek Banks |
| Stream S1 Enos Creek | ➢ Wetland W1 | WQ | **Bio-filtration Source Controls**<br>**Bio-filtration Regional Facility** | • Roadside rain gardens<br>• Regional treatment/detention |
| | | Volume ↓<br>Rate Control | ~~Armour Creek Banks,~~ **Detention,**<br>~~Diversion~~ | • Detention facility upstream of wetland |
| Enos Lake | Stream S3<br>➢ Wetland W2 | WQ | **Bio-filtration Source Controls**<br>Bio-filtration Regional Facility | • Roadside rain gardens |
| | | Volume ↓<br>Rate Control | Armour Creek Banks,-**Detention,**<br>~~Diversion~~ | • Utilize large wetland W1, 11% of catchment area, as detention |
| Enos Lake | Stream S4 | WQ only | **Bio-filtration Source Controls**<br>~~Bio-filtration Regional Facility~~ | • Roadside rain gardens<br>• Realign to rainwater creek outlet only |
| Enos Lake | Stream S5<br>➢ Wetland W3 | WQ | **Bio-filtration Source Controls**<br>Bio-filtration Regional Facility | • Roadside rain gardens |
| | | Volume ↓<br>Rate Control | Armour Creek Banks,-Detention,<br>Diversion | • Divert high flows around wetland to lake * |
| Enos Lake | Stream S6<br>➢ Wetland W4<br>➢ Wetland W5 | WQ | **Bio-filtration Source Controls** | • Roadside rain gardens |
| | | Volume ↓<br>Rate Control | **Detention** | • Utilize large wetland W4, 11% of catchment area, as detention |
| Enos Lake | Stream S7<br>➢ Wetland W6 | WQ | **Bio-filtration Source Controls** | • Roadside rain gardens |
| | | Volume ↓<br>Rate Control | **Detention** – very small development area | • Provide detention or divert high flows around wetland |
| Enos Lake | Stream S8 | N/A | N/A | • Realign to rainwater creek outlet only<br>• Roof leaders to rock pits, overflow to lake |
| Enos Lake | Stream 11<br>➢ Wetland W7 | WQ<br>Volume ↓<br>Rate Control | **Bio-filtration Regional Facility** because detention if also required | • Expand and modify existing ponds to provide treatment/detention facility |
| Enos Lake | Direct Outfalls to Lake | WQ only | **Bio-filtration Source Controls**<br>~~Bio-filtration Regional Facility~~ | • Roadside rain gardens<br>• Outfalls that aerate flows to increase DO in lake |
| Dolphin Lake | Stream 10<br>➢ Wetland W8<br>➢ Wetland W9 | WQ<br>Volume ↓<br>Rate Control | **Bio-filtration Regional Facility** because detention is also required | • Combined treatment/detention facility U/S of Wetland W8<br>• Utilize Wetland W9 for detention |
| Dolphin Lake | Direct Outfalls to Lake | WQ only | **Bio-filtration Source Controls** | • Roadside rain gardens |

Volume ↓ = Volume Reduction, bio-retention rain gardens also provide volume reduction
~~Strikethrough text~~ = not preferred option **Bold** = preferred option
* Integrated team to determine if wetland/creek protection is a priority. DO = dissolved oxygen

## 3.9 Hydrologic Impact to Wetlands

The Detailed Biophysical Assessment for The Lakes District conducted by Cascadia Biological Services (February 2009) identified a few different species using the various wetlands on the property. Rough-skinned newt, Pacific chorus frog and red-legged frogs inhabit wetlands onsite and likely breed in multiple wetlands in the area during the late-winter to spring period. These species deposit their eggs in ponds, typically attaching them to submerged vegetation. The ponds onsite provide a diversity of depths and semi-aquatic vegetation for these amphibians to choose from for breeding opportunities. It is expected that the addition of clean stormwater inputs to wetlands will continue to allow these amphibians to use the fringes of the ponds for breeding as they do now. The ISMP aims to ensure that any changes to the hydrology continue to provide suitable breeding opportunities for these species.

To estimate the potential water level fluctuation in each wetland, an assessment was undertaken by modelling the pre-development and post-development tributary catchment inflows, outflows, and storage volumes, using a SWMM model. The pre- and post-development catchments are shown on Figure 15 and wetland assessment is summarized in Table 14. Outflows and storage volumes were coarsely estimated because survey information is not currently available. The results show that unmitigated post-development flows would have significant effects on some of the wetlands - W3, W6, and W8 especially small wetlands with large tributary areas. The larger wetlands – W2, W4, W9 appear to be able to absorb the flow increases with little impact to peak water levels or water level fluctuation.

For the wetlands that appear heavily impacted, a variety of solutions are proposed. It is recommended that W3, W5 and W6 have a diversion to direct peak flows to Enos Lake, while allowing baseflows and low flows to the wetlands to be maintained. W1 requires a separate 2,300 $m^3$ detention facility to detain the peak flows from the catchment downstream of Enos Lake and also to provide water quality treatment for untreated roads. W7 requires upstream detention, but it is proposed that the existing RWM ponds be modified to provide the required 4,850 $m^3$ of detention. The drainage system draining to W5 requires a flow split to direct baseflows and low flows to the wetland, as the catchment area is greatly reduced in the post-development scenario. W2, W4, and W9 will be used for detention with outlet modifications to ensure proper operation. Appendix A contains the exceedance duration curves for each wetland. Detention ponds will detain post-development flows to pre-development values. The required detention volume was estimated using a detention storage spreadsheet using a 5-year design event, but will be further refined during detailed design.

To monitor the continued use of the wetlands by amphibians, an amphibian breeding survey can be conducted every 2 years to observe the presence and distribution of egg masses in the ponds, and undertake an assessment of the quality of breeding habitat. This information will aid in understanding how the development and stormwater management may be affecting these species, if at all, and inform any adaptive management measures.

Outlet modifications are also required for safety reasons. Most of the wetlands were created by existing or past beaver dams. The W1 beaver dam on Enos Creek S1 has failed previously and resulted in flooding of a property downstream on Cormorant Crescent. Construction of berms behind a few of these dams (Wetland W1 on Enos Creek S1, Wetland W2 on Stream S3, and Wetland W4 on Stream S6) is required to protect property in the case of Enos Creek and for habitat protection for the others. A failure in the beaver dam could lead to serious erosive degradation of the downstream creeks. Provide erosion protection at storm sewer outfalls to minimize erosion. Keep drainage areas to wetlands to sustain flows.

**Table 14: Assessment of the Hydrologic Impacts to Existing Wetlands**

| | Wetland | | Pre-Development | | | | | Post-Development | | | | | | Required U/S Detention Volume[3] ($m^3$) | Required Detention Depth in Wetland (m) | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ID | Surface Area ($m^2$) | Catchment Area (ha) | TIA[1] (%) | Water Level Fluctuation[2] (m) | Peak Depth Above Outlet (m) | Catchment Area (ha) | △ Catchment Area (%) | TIA[1] (%) | Unmitigated Water Level Fluctuation[2] (m) | Peak Depth Above Outlet[2] (m) | △ Peak Water Level Increase[2] (m) | | | | |
| | W1 | 13,100 | 276<br>27 dev area | 11% | 0.74 | 0.36 | 276<br>23 dev area | 3% | 54% | 0.73 | 0.36 | 0.01 | | 2300[4] | 1.76 | Separate detention facility for development downstream of lake, also provide water quality treatment for untreated roads. |
| Drains to Enos Lake | W2 | 9,950 | 8.1 | 5% | 0.58 | 0.04 | 8.9 | 10% | 59% | 0.55 | 0.05 | 0.00 | | 1,400 | 0.14 | Minimal impact, Utilize Wetland W2 for detention. |
| | W3 | 794 | 2.0 | 5% | 0.52 | 0.02 | 3.9 | 95% | 55% | 0.49 | 0.03 | 0.01 | | 760 | 0.96 | Detention depth too large in wetland. Construct flow splitter to convey low flows to wetland & divert high flows to lake. |
| | W4 | 25,100 | 76.1 | 19% | 0.70 | 0.20 | 65.7 | -14% | 25% | 0.66 | 0.18 | -0.02 | | 3,900 | 0.16 | Marginal impact, Utilize Wetland W4 for detention. |
| | W5 | 8,170 | 11.6 | 35% | 0.56 | 0.06 | 2.9 | -75% | 53% | 0.58 | 0.02 | -0.04 | | 0 | 0.00 | Need more flow to sustain wetland. Construct flow splitter to convey low flows to wetland & divert high flows to lake |
| | W6 | 770 | 21.4 | 24% | 0.52 | 0.09 | 22.7 | 6% | 31% | 0.40 | 0.09 | 0.00 | | 1,600 | 2.08 | Detention depth too large in wetland. Construct flow splitter to convey low flows to wetland & divert high flows to lake. |
| | W7 | 8,390 | 41.5 | 27% | 0.62 | 0.14 | 48.8 | 18% | 42% | 0.60 | 0.15 | 0.02 | | 4,850 | 0.58 | Utilize u/s RWM ponds to detain flow prior to discharge to wetland. |
| | W8 | 357 | 0.4 | 5% | 0.53 | 0.01 | 0.83 | 108% | 43% | 0.49 | 0.01 | 0.00 | | 360 | 1.01 | Construct upstream detention pond to minimize impact |
| | W9 | 4,560 | 22.9 | 34% | 0.57 | 0.09 | 22.9 | 0% | 51% | 0.57 | 0.09 | 0.00 | | 275 | 0.06 | Minimal impact, Utilize Wetland W9 for detention. |

Legend:

| | | | | |
|---|---|---|---|---|
| **Construct Detention U/S** | slight increase | slight increase | >0.2m | **Construct Detention U/S** |
| **Utilize Wetland for Detention** | large increase | large increase | | **Utilize Wetland for Detention** |
| **Divert High Flows Around Wetland** | decrease | decrease | | **Divert High Flows Around Wetland** |

Refer to Figure 15

Wetland outlet assumed to be 3 m wide weirs

1. TIA values do not include the wetland areas.
2. WL fluctuation and Peak WL values are based on the 9 year continuous modeling results.
3. Required detention volume is based on detaining the 5-year post-development peak flows to pre-development values.
4. Detention Vol based on 23 ha development area downstream of lake

△ = Change between pre-development and post-development

# 4. Integrated Stormwater Management Plan

The land use planning for Fairwinds far exceeds current practices in land development, and implements environmental best management practices. An unprecedented 40% + of the neighbourhood is protected as green space, building footprints are reduced, and stormwater best management practices are envisioned.

## 4.1 The ISMP Plan

The ISMP is summarized in Figure 16 and Table 14.

The ISMP for Fairwinds, consists of many components for:

- Minor and major drainage system;
- Conserving wetlands, watercourses, riparian and ESA;
- Best management practices to mitigate the impacts of future development;

Table 14 summarizes and prioritizes all the ISMP components and responsibility for implementation.

## 4.2 Roadside Rain Gardens

### Proposed Road Slopes in Fairwinds

Maximum road gradients have been agreed with Ministry of Highways and Transportation, as part of the specific design criteria developed for the Fairwinds development. The gradients for the following road classifications are as follows:

- Parkway collector, 50kph: 9%
- Minor Collector, 50kph: 10%
- Urban local, 50kph: 10%
- Urban local, 30kph: 12% on tangent /10% on curves

Figure 13 depicts roads greater than and less than 10%.

Road profiles have been drawn in ACAD and reviewed to confirm that the gradients can be achieved for the alignments proposed in the Neighbourhood Plan. Generally the gradients meet the gradient criteria. Some roads require adjustment to their alignment to reduce gradients (and minimize depths of excavation or fill), and solutions have been identified, in some cases with more than one option. The profiles and alignments are in a state of “red mark” and were not finalized as the Neighbourhood Plan road layout is not a Final Subdivision Plan. The profiles can be supplied for review on request.

### Rain Gardens for Water Quality Treatment

Roadside rain gardens have been maximized throughout the development and are proposed on all roads with less than 10% grade as shown on Figures 13 and 16. Rain gardens will be on one side of the road as shown in Figure 14. This figure also shows example grading and drainage system configuration on both public and private property. Rain gardens will be lined to minimize bedrock fractures from conveying water to unanticipated locations and causing flooding problems.

**Table 15: Fairwinds ISMP Plan & Implementation Strategy**

| | Proposed ISMP | Priority | Responsibility |
|---|---|---|---|
| **Drainage System – Safe Flood Conveyance** | | | |
| 1. | **MINOR SYSTEM** | | |
| | • Site grading (on lots downslope of roads, only pervious areas draining to downhill areas, roof leaders connected to storm sewer). Lots will not drain toward other lots, but toward roadways or municipal right-of-ways with drainage swales that direct runoff to the municipal drainage system.<br>• Storm sewers along all roads.<br>• All impervious areas, including roof leaders, drain to storm sewers unless lot is adjacent to natural area than roof leaders to rock pits.<br>• Construct berm upstream of existing beaver dam on Wetland W1 on Enos Creek S1 to protect downstream properties from potential flooding and erosion in the event of beaver dam failure. | At time of development | Developer |
| 2. | **MAJOR SYSTEM** | | |
| | • Site grading.<br>• Roadway overland flow route to existing wetlands, creeks, lakes.<br>• Outfalls to Enos Lake should be designed to increase aeration to increase dissolved oxygen. This can be in the form of 'rainwater creeks' with rock roughness or piped outlets with energy dissipaters whichever is most appropriate to contain flows from eroding steep drop-offs to lake.<br>• Check that existing creeks can safely convey 100-year post-development peak flows. If not, assess creek channel improvements or diversion of high flows to receiving water (lake, ocean).<br>• Roadway overland flow route to existing wetlands, creeks, lakes.<br>• Construct cutoff ditches for undeveloped upland area runoff along the west edge of the development. | At time of development | Developer |
| **Conserve Environmental Values** | | | |
| 3. | **CONSERVE ENVIRONMENTALLY SENSITIVE AREAS - PROTECT RIPARIAN & WETLAND AREAS** to protect watershed health | | |
| | • Preserve natural wetlands, creeks, lakes and their riparian setbacks.<br>• Conserve environmentally sensitive areas through park dedications and permit areas.<br>• Require appropriate geotechnical setbacks from steep slopes. | Prior to development | Developer / RDN |
| **Mitigation of the Impacts of Future Development** | | | |
| 4. | **CONSTRUCT HYDROLOGIC VOLUME REDUCTION MEASURES** to maintain baseflows and minimize downstream erosion | | |
| | • For development draining to existing creeks (excluding areas that are piped into the lakes or ocean):<br>- 300 mm topsoil for landscape and irrigated areas.<br>- Maximize low impact development techniques.<br>- Drain roof leaders to rock pits for lots adjacent, and upslope, to natural areas.<br>- Construct Stormwater Source Controls (bio-retention rain gardens or swales). Size to capture 50% of the 2-year, 24-hour event (29mm) or regional facilities for baseflow release. | At time of development | Developer |
| 5. | **CONSTRUCT STORMWATER QUALITY TREATMENT MEASURES** to treat runoff prior to discharge to water bodies | | |
| | • For all development:<br>- Roadside rain gardens with underlying rock trenches with perforated pipe draining to storm sewer every 100 m +/-. Rain gardens to be lined to manage unintended groundwater seeps.<br>- Construct water quality treatment source controls (absorbent landscaping, rain gardens, swales, etc.). Size to treat 90% of average annual runoff.<br>- Construct regional water quality facilities such as wetlands and wet ponds for areas where source controls are not able to meet the target.<br>- Provide *Erosion and Sediment Control* measures during construction. | At time of development | Developer |
| 6. | **CONSTRUCT HYDROLOGIC RATE CONTROL MEASURES** to minimize downstream erosion | | |
| | • For development draining to existing creeks (excluding areas that are piped into the lakes or ocean):<br>- Construct regional detention facilities. Size to detain 6-month, 2-year, and 5-year events.<br>- Upgrade existing detention ponds south of Enos Lake, near Fairwinds Drive and Bonnington Drive, to detain the flow from the additional development.<br>- Utilize Wetlands W2 and W4 for detention.<br>• For development draining directly to lakes:<br>- Utilize lake storage to detain flows in the downstream creek by adjusting the lake outlets, as required. | At time of development | Developer |
| **Erosion Management** | | | |
| 7. | **REHABILITATE EXISTING EROSION SITES** | | |
| | • Construct erosion protection at Schooner Cove Southern Catchment on the beach between the end of the culvert and the head of the beach. | At time of development | Developer |
| 8. | **EROSION PREVENTION MEASURES** | | |
| | • Construct berms behind of existing beaver dams on Wetland W2 on Stream S3, and Wetland W4 on Stream S6. Beaver dam failures could lead to serious erosive degradation of the downstream creeks.<br>• Monitor Enos Creek (Stream S1) erosion downstream of the beaver dam. | Prior to development | Developer |
| **Management Program** | | | |
| 9. | **'DEVELOP WITH CARE' MANAGEMENT MEASURES** | | |
| | • Protect water quality during construction, ensure Erosion & Sediment Control Plans and implementation.<br>• Avoid disturbing environmentally valuable resources during development, limit access to ESAs.<br>• Schedule construction activities to avoid sensitive time periods.<br>• Restore disturbed areas.<br>• Prohibit the use of fertilizers within the Enos Lake watershed to manage nutrient levels.<br>• Limit Enos Lake access points to protect Stickleback littoral habitat and macrophyte beds. | Immediate | Developer<br>RDN |
| 10. | **FURTHER STUDIES** | | |
| | • Investigate combining detention into roadside rain gardens to reduce need for regional facilities. Check rain gardens suitability relative to overland flow routes. Size and design roadside rain gardens, proposed detention facilities and wetland/lake outlets.<br>• Collect daily Enos Lake water level data and detailed pumping records, and undertake detailed water balance modelling to determine lake outlet modifications.<br>• Determine environmental enhancement opportunities.<br>• Develop green road standards including linear stormwater treatment rain gardens (lined).<br>• Include stormwater awareness and stewardship in homeowners manual. Encourage residents to proactively prevent stormwater degradation and rain garden maintenance. | Upon approval of this ISMP | Developer |
| 11. | **WATERSHED MONITORING** | | |
| | • Conduct watershed performance monitoring and adaptive management approach. | Ongoing | Developer<br>RDN |
| Note: Refer to Figure 14. | | | |

## Rain Gardens in Silver Ridge Residential Subdivision Example

Roadside rain gardens were designed and constructed in January 2004 at Silver Ridge in Maple Ridge (annual rainfall 2300 mm compared with Nanoose Bay 910 mm).

**2004**

**2005**

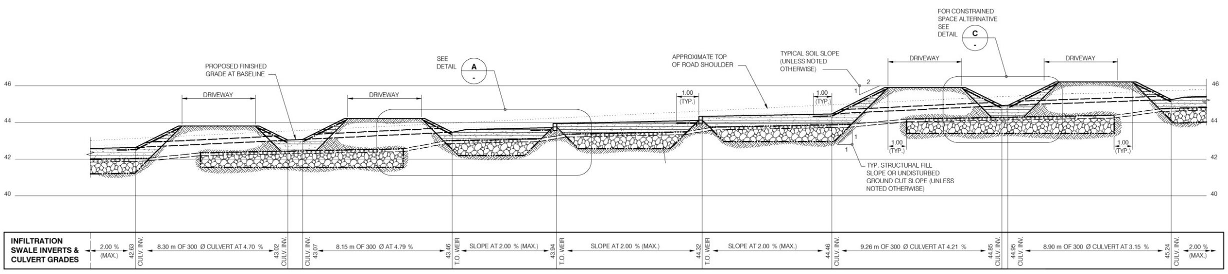
**2008**

**2012**

### Steep Site and Roads

The site is steeply sloped and comprises rolling bedrock terrain overlain with glacial till, with slopes varying from 12 to 25 percent. Road slopes range from 2% to 15%.

Bolted timber weirs were constructed to limit the linear grades to 2% slope to encourage surface water infiltration. The weir positions were determined by the adjacent shoulder grade with the top weir at 300 mm below the shoulder. The weir drop was about 200 mm for roads less than 5% slope and about 400 mm for slopes between 5% and 10%.

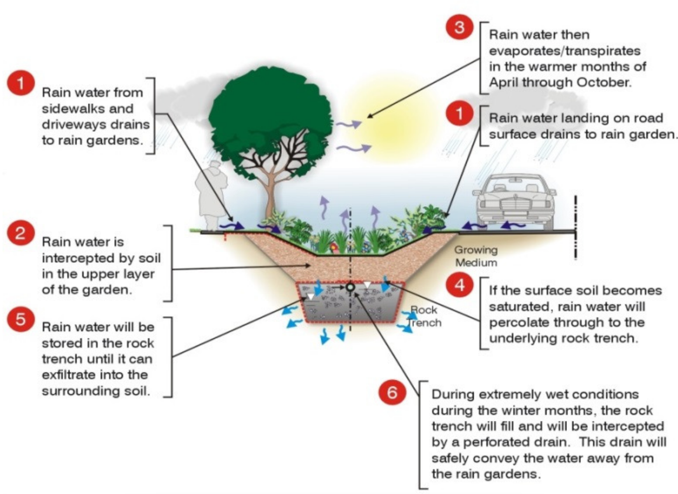


TYPICAL INFILTRATION SWALE PROFILE
SCALE 1:100

## How It Works

Roadside rain gardens were constructed on one side of the road within the 20 m road right of way. They were designed to collect, store, infiltrate and evaporate runoff from the road and driveway surfaces for rainfall events up to the 6-month, 24-hour return period. Runoff greater than the 6-month, 24-hour events overflow through ditch inlets into the storm sewer system and the gardens were reinforced with erosion protection fabrics as they form part of the 100-year overland flow path. The gardens will also slow the response of larger storms on the downstream infrastructure. They are attractively landscaped to provide for evaporation and transpiration, and to visually enhance the community.

During minor storm events stormwater is collected by the rain gardens and the engineered absorbent soils store or hold runoff until it’s depleted by evapotranspiration. When the volume of runoff exceeds the saturation capacity of the soil, the water drains into the subsurface rock trench and infiltrates into the native till soils. If the incoming flow rate exceeds the natural infiltration rate then the runoff will accumulate in the rock trench; if the trench capacity is exceeded, a 150 mm diameter perforated overflow pipe at the top of the trench will collect and convey excess stormwater to the next downstream manhole to the storm sewer system. The following graphic shows the rain garden swale design and operation concept.




Note: Fairwinds rain gardens are to be lined to minimize bedrock fractures from conveying water to unanticipated locations and causing flooding problems.

Excess stormwater can also be conveyed overland along the surface of the rain garden to ultimately drain through inlets to the storm sewer system or to the roadway overland flow path. The rain gardens have 600 mm thick absorbent soil layers that enhance plant growth and drainage. The underlying rock trenches were typically a minimum depth of 0.8 m below the perforated pipe, and contained 50 mm to 150 mm drain rock having a porosity of 35%.

**Performance Monitoring Results**

Flow monitoring equipment was installed in 2005 and data was collected for three years. The performance of the roadside rain garden was evaluated under different real storm events. Results indicate that the roadside rain gardens are effective in meeting the volume reduction targets and water quality objectives for both dry and saturated conditions, and are also providing attenuation for events greater than the 6-month as they are passed through the rain garden absorbent soil layer and rock trench system. The rain gardens are capturing 80% to 88% of frequently occurring rainfall events (less than 5-year events) under both dry and wet conditions. The analysis of water levels within the rain garden's rock trench showed that the infiltration rate ranged between 0.5 mm/hr to 1.1 mm/hr and the average rate was 0.8 mm/hr, which is reasonably close to the assume design value of 1.0 mm/hr for till soils.

For additional information, please refer to the CWRA 2006 National Conference paper and presentation entitled *Silver Ridge Low Impact Residential Development* http://www.kwl.ca/kbase/silver-ridge-low-impact-residential-development.

### Rain Garden Design Lessons Learned

KWL has been sizing, designing and constructing rain gardens since 2004 and authored the *Metro Vancouver Stormwater Source Control Guidelines 2005, Updated 2012*. Much has been learned and is summarized in the *Top 10 Considerations for Rain Garden Design* paper and presentation at WEFTEC, Chicago, October 2013 http://www.kwl.ca/kbase/top-ten-design-considerations-rain-gardens. *Top 10 Maintenance Considerations* are also summarized http://www.kwl.ca/kbase/stormwater-rain-gardens-102-%E2%80%93-top-10-implementation-and-maintenance-considerations.

## 4.3 Performance Monitoring and Adaptive Management

To ensure the ISMP plan is unfolding as intended, a Performance Monitoring and Adaptive Management Program is recommended. Preserving the ecological health of natural systems is not easy. It requires a comprehensive planning process and the ability to reassess and redirect efforts as required over time. It is important to monitor the impacts of development and the performance of implemented works and programs to assess if they are effectively meeting the ISMP goals. The data must be interpreted carefully and if the results are less than satisfactory, the program must be re-examined and efforts realigned. This is particularly important with rapidly evolving stormwater management technologies.

PGL's *Terms of Reference – Enos Lake Protection and Monitoring Program Memorandum*, 2013 is included in Appendix B. An Enos Lake Monitoring Program is yet to be developed according to the ToR. This process will develop performance indicators specific for Enos Lake, therefore Enos Lake performance indicators discussed in this section are for consideration only and are to be confirmed through the Enos Lake Monitoring Program.

Each indicator must be tracked over the long term in order to be useful in evaluating changes in the water bodies. The indicators do not have to all move in a particular direction, up or down, in order to show maintenance or degradation in overall watershed health. Rather the tracked suite of indicators should be reviewed every few years to:

- Note movement in particular indicators,
- Evaluate possible causes of the movement,
- Determine if the movement of the indicators represents an impact,
- Evaluate if the indicator movement is expected or unforeseen, and
- Review the goals, elements, and implementation plan of the ISMP to assess if changes should be made to the plan in order to remain on track and achieve the overall stormwater goals over the implementation timeline for the ISMP.

The schedule for a full assessment and review for the watershed health indicators should be at least once every two to five years depending on the amount of development activity in the study area and change in indicator values. Therefore, four to ten full reviews of the indicators should occur during a 20-year expected timeline for implementation, and tracking to assess the impacts of full implementation should be continued by the Regional District, at least once every five years, beyond that horizon.

Performance monitoring is the repeated collection of measurements to measure changes or trends in environmental condition. For the Fairwinds ISMP, the monitoring program should focus on two essential questions:

1. Is new development negatively impacting the ecological health of creeks, wetlands and lakes?
2. Are stormwater management activities maintaining the overall condition (health) of the water bodies?

Specific questions and detailed methods for answering them should be developed before any monitoring is undertaken. It is also critical to establish existing baseline conditions for each parameter.

Table 16 lists a variety of parameters or “indicators” that may be measured and tracked over time. The general measurement approach, as well as the need for 2013 baseline values, and expected changes for each water body performance indicator are summarized.

# 5. Recommendations

Based on the foregoing, it is recommended that Bentall Kennedy:

1. Obtain feedback and endorsement from regulatory agencies for this ISMP.
2. Investigate combining detention into roadside rain gardens to reduce need for regional facilities. Check rain gardens suitability relative to overland flow routes. Determine sizing for roadside rain gardens, proposed detention facilities and wetland/lake outlets.
3. Conduct continuous lake water level monitoring, together with detailed record keeping of lake withdrawals (pumping) for a few years to obtain data for more accurate water balance modelling to make recommendations on lake outlet modifications.
4. Develop typical details and specifications for roadside rain gardens and disconnected roof leaders to rock pits that are adjacent to undeveloped areas.
5. Commit to monitoring and review of Watershed Performance Indicators on a recurring basis, minimum every five years and undertake adaptive management measures if needed.

**Table 16: Fairwinds ISMP Performance Indicators**

| | Performance Indicator | Method of Analysis | 2013 | 2015 |
|---|---|---|---|---|
| **Overall Study Areas** | | | | |
| 1. | Planned Future TIA (% of Watershed Area) | GIS Analysis of Aerial Photos and Assessment Data | 36%[1] to mouth of Enos Creek 43%[1] Dolphin Lake | Less than planned TIA (20 yr development) |
| 2. | Riparian Area (% of Riparian Area) | GIS Analysis of Aerial Photos every 2 to 5 years | 100% | Decrease expected due to development under RAR |
| **Enos Lake** (To be completed under the *Enos Lake Protection and Monitoring Program*, but may include the following) | | | | |
| | **Stickleback Health** | | | |
| 3. | Fish Population in Enos Lake | Density, species composition Fish counting data | Limited and out-of-date data | Collect data |
| 4. | Extent of Littoral Habitat (m2) | Mapping | | |
| 5. | Extent of Macrophyte Beds (m2) | Field Inventory | | |
| | **Flow Regime** because species at risk are sensitive to shoreline habitat changes | | | |
| 6. | Min Summer Low Water Level (m) | Continuous flow measurement at Enos Lake and modelling | EBD | No decrease |
| 7. | 200-year High Water Level (m) | | EBD | Same or decrease |
| 8. | Water Licence Withdrawals | | EBD | Same |
| | **Water Quality** | | | |
| 10. | Average Summer Water Temp (°C) | | EBD | Same or Decrease |
| 11. | Dissolved Oxygen (mg/L) | | | Same or Increase |
| 12. | Water pH | | | |
| 13. | Specific Conductivity (μS/cm) | | | Same or Decrease |
| 14. | Turbidity (NTU) | | | Decrease |
| 15. | Fecal Coliforms (MPN/100mL) | Water Quality Sampling, every 2 years? | EBD | < 200 |
| 16. | Nitrogen (mg/L) | | ? | |
| 17. | Phosphorus (mg/L) | | ? | |
| 18. | Total Alkalinity (units) | | ? | |
| **Streams** | | | | |
| 19. | No. of Erosion Sites within streams, wetlands, shores | Field reconnaissance | 2 (Enos Lake outlet and Stream S7) | Same or Decrease |
| **Wetlands** | | | | |
| 20. | Amphibian Breeding Survey | Observe presence & distribution of egg masses & quality of breeding habitat, every 2 years | EBD | Same |

1. Impervious area includes wetland areas, but not lake areas.
EBD – Establish Baseline Data

## 5.1 References

Center for Watershed Protection, *National Pollutant Removal Performance Database.* Version 3 September, 2007.

Charles River Watershed Association, *Low Impact Best Management Practice,* Information Sheet.

Coffman, Larry S., *Low–Impact Development Design: A New Paradigm for Stormwater Management Mimicking and Restoring the Natural Hydrologic Regime - An Alternative Stormwater Management Technology,* Prince George's County, Maryland; Not Dated.

Davis, Allen P., Rebecca Stack, Patrick Kangas, and J. Scott Angle, *Water Quality Improvement Using Rain Gardens: University Of Maryland Studies*, Maryland Water Resources Research Center; Not Dated (post 2003).

Debo, Thomas Neil, and Andrew J Reese, *Municipal Stormwater Management*, 2nd Ed. 2003.

Dougherty, LeBleu, and Brantley, *Evaluating Bioretention Contaminant Uptake and Removal in an Experimental Rain Garden Study, March 1, 2008 - February 28, 2007*. Fiscal year 2008 Report; Auburn, Alabama.

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Minton, Gary R., PhD., P.E., *Stormwater Treatment: Biological, Chemical & Engineering Principles*, Published by Resource Planning Associate, Seattle, WA. ©2005.

*Pennsylvania Stormwater Best Management Practices Manual.* Prepared for the Pennsylvania Department of Environmental Protection, Bureau of Stormwater Management,Division of Waterways, Wetlands, and Erosion Control; Draft - January 2005.

*Urban Design Tools - Low Impact Development,* web site,

http://www.lid-stormwater.net/bio_benefits.htm

## 5.2 Report Submission

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## Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of Bentall Kennedy (Canada) LP for the Lakes District and Schooner Cove Integrated Stormwater Management Plan. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

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## Revision History

| Revision # | Date | Status | Revision | Author |
|---|---|---|---|---|
| 1 | October 2013 | Draft | Update to ISMP | C. Campbell |
| 2 | November 2013 | Final | Update based on RDN comments | C. Campbell |

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Appendix A

# Background

# Appendix A

## Contents



## Tables

# AppendixA – Watershed Overview

## Figures

# Appendix A

## A.1 Background Information

The available background reports are summarized as follows.

**Table A-1: Background Reports**

| | Date | Report Title/Author |
|---|---|---|
| Engineering | Jul 2012 | The Lakes District & Schooner Cove Draft ISMP – KWL |
| | Jul 2012 | Fairwinds Lakes District & Schooner Cove Rainwater Management Standards – KWL |
| | Jun 2008 | Preliminary Geotechnical Terrain Assessment for Proposed Subdivision Fairwinds Neighbourhood 2, Nanoose Bay, B.C. – Trow |
| Land Use Planning | Jun 2013 | The Lakes District Regional Park Masterplan & Development Guidelines, Ekistics |
| | Jul 2012 | Fairwinds Resort Community Project Specific Street Standards – Ekistics, |
| | Feb 2011 | The Lakes District Neighbourhood Plan, Ekistics - Section 4.3.3 Master Rainwater Concept, Schooner Cove Neighbourhood Plan, Ekistics |
| | Dec 2010 | The Lakes District Neighbourhood Plan Background Summary, Ekistics<br>Schooner Cove Neighbourhood Plan Background Summary, Ekistics |
| | Sep 2013 | The Lakes District Infrastructure Phasing & Land Use Phasing Plan – Ekistics |
| | Sep 2013 | Schooner Cove Infrastructure Phasing & Land Use Phasing Plan – Ekistics |
| Environmental | Jul 2013 | Terms of Reference, Enos Lake Protection & Monitoring Program – PGL |
| | Feb 2010 | Environmental Impact Assessment – Pottinger Gaherty Environmental |
| | Feb 2009 | Detailed Biophysical Assessment – Cascadia Biological Services |
| | Stickleback Reports | |
| | 2012 | Assessment and Status Report on the Enos Lake Benthic and Limnetic Threespine Stickleback Species Pair - COSEWIC |
| | Jul 2007 | Recovery Strategy for Paxton Lake, Enos Lake, and Varanda Creek Stickleback Species Pairs in Canada, DFO |
| | Water Quality Reports | |
| | May 2013 | Early Spring 2013 Enos Lake Water Quality Monitoring Results – AquaTerra |
| | Oct 2012 | Water Quality Monitoring Report for Enos Lake, Nanoose Bay – MacDonald Environmental Services Ltd. |
| | Dec 2011 | Fall 2011 Enos Lake Water Quality Monitoring Results – AquaTerra |
| | Jun 2011 | Spring 2011 Enos Lake Water Quality Monitoring Results – AquaTerra |
| | Jan 2011 | Fall 2010 Enos Lake Water Quality Monitoring Results – AquaTerra |
| | May 2010 | Spring 2010 Enos Lake Water Quality Monitoring Results – AquaTerra |
| | Dec 2009 | Fall 2009 Enos Lake Water Quality Monitoring Results – AquaTerra |

# Appendix A

| | Date | Report Title/Author |
|---|---|---|
| | Apr 2009 | Spring 2009 Water Quality, Enos Lake and Enos Wetland - AquaTerra |
| | Nov 2008 | Fall 2008 Water Quality, Enos Lake and Enos Wetland - AquaTerra |
| | May 2008 | Spring 2008 Water Quality, Enos Lake and Enos Wetland - AquaTerra |
| | Dec 2007<br>May 2007 | Baseline Water Quality – Keystone Environmental |

## A.2 MOTI Drainage Criteria

The 2007 *BC MoT Supplement to TAC Geometric Design Guide, Section 1000, Hydraulics Chapter* are the governing criteria to be used, specifically the following subsections of the Guide:

**Section § 1010.02**

**Table A-2: Design Return Periods Specified for Hydraulic Structures**

| Hydraulic Structures | Design Return Periods by Road Classification | | Design Return Period Used for Fairwinds SWMP |
|---|---|---|---|
| | Low Volume | Local | |
| Highway Ditches | 10 to 25 | 10 to 25 | 100 for capacity,<br>10 for erosion |
| Culverts < 3m span | 50 to 100 | 50 to 100 | 100 |
| River Training and Control Works | 100 | 200 | n/a |

**Section § 1010.03 - Requirements for Development Drainage Design**

- Minor system to be designed for “frequently occurring storms (e.g. less than 5-year to 10-year return period)”.
- Major system to be designed to convey a 100-year return period peak discharge.
- All drainage systems must include runoff controls to limit post-development peak-discharge rates to the pre-development rates for 5-year return period storms.
- Additional requirement – assess the receiving ditch or watercourse for peak flows between 5 and 100-year return period. Assessment must document any net change in water velocity, identify impacts from increased peak flows, and make recommendations for mitigation; i.e. flows must be managed to ensure no increase in flooding and stream erosion occur as a result of development storm drainage.

According to MoT guidelines, submitted Drainage Reports are recommended to include:

- a hydrograph method to calculate design run-off volumes;

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- check of several storm durations for storage requirements to identify the maximum storage volume;
- 24-hour duration rainfall checked for coastal areas;
- continuous simulation may be used in place of design storms for sizing storage volumes and assessing stream impacts;
- documentation is required to show that un-attenuated flood waters in excess of the 5 year discharge that by-pass the detention facility must not adversely affect the receiving ditch or channel; and
- Any facility should have 100-year emergency (spillway) capacity to downstream watercourse.

Standard engineering practice requires that the stormwater management system provide adequate conveyance capacity for post-development flows. In general, the minor drainage system, including storm sewers, and culverts, should be designed to carry the 10-year peak flow as a minimum. The major system should include flood conveyance routes for carrying the 100-year peak flows.

## A.3 Water Balance Modelling of Lakes

### Data Inputs

#### Recorded Lake Levels

Fairwinds has been collecting manual water level measurements at the Enos Lake outlet weir approximately once a month between January 2002 and December 2012. Water levels in Dolphin Lake are not recorded.

#### Recorded Precipitation

Daily rainfall totals from the *Nanaimo City Yard* AES climate station between 2002 to 2010 were scaled down by approximately 20% to represent Fairwinds lower rainfall totals. Nanaimo (23 year period of record) has an annual average rainfall of 1141 mm compared with Fairwinds (22 year period of record) with 913 mm (from their records). Fairwinds area receives 20% lower annual average rainfall.

#### Typical Evaporation Rates

Evaporation values used were based on established typical monthly values for the Greater Vancouver Region.

#### Observed Lake Outflows

Data representing water losses from the lake such as how much and how frequently water spilled over the weir outlets or flowed out of the outlet was not available.

#### Enos Lake Withdrawals

Water is pumped from Enos Lake to Dolphin Lake, and then flows from Dolphin Lake into watercourse S9 through the Fairwinds Golf Course ponds which are used to irrigate the Golf Course during the summer months. Detailed pumping records were not available but the pumping time period and total volume pumped were available for 2009. This data was used to estimate a constant daily pump volume

# Appendix A

that was removed from Enos Lake and added to Dolphin Lake in the water balance calculations during June, July, and August each year.

### Lake Outlet Structures

Enos Lake is controlled by a 900 mm diameter culvert with a concrete headwall with an upstream invert elevation of 45.83 m. There is a weir at the upstream edge of the headwall which prevents outflows until a water level of 46.2 m is exceeded.

Dolphin Lake is controlled by two siphons (one 3" and one 4") that convey water from the lake, over a beaver dam upstream of the lake culvert outlet structure, and into the creek downstream. Detailed information was not available, however to determine a siphon flow rate, it was assumed that the difference in water levels between the upstream and downstream sides of the siphon was 1 meter. This was used to calculate a possible siphon flow of 25 L/s. To account for seepage from the lake the siphon flow was doubled to 50 L/s, which is believed to be in line with similar structures and the flow observed downstream of the lake. This 50 L/s was as a constant outflow applied to the water balance calculations.

The existing lake outlet structures were used in both the pre-and post-development models. No adjustments were made in the water balance calculations to the outlets to reduce the post-development peak outflows to pre-development values.

### Lake Catchment Areas

One drainage catchment per lake was delineated and input into the model (see Figure 5). The areas used were 249 ha for the Enos Lake catchment and 81 ha for the Dolphin Lake catchment in pre-development and 259 ha for Enos Lake catchment and 84 ha for Dolphin Lake catchment in post-development.

## Enos Lake Water Balance Validation

The water balance model was validated by comparing the recorded monthly water levels to the model results. Runoff coefficients for catchments draining to Enos Lake were estimated based on pre-development land use and adjusted until the modelled and recorded water levels generally agreed.

Figure 8 shows the recorded and modelled water levels for Enos Lake. The validation shows a generally good fit with average recorded lake water levels. The validation was not a perfect fit because the recorded water levels were only monthly snapshots and pumping rates were based on one year of data but in reality were variable based on the weather conditions of each individual summer.

In general, the model was able to simulate the validation period sufficiently for its intended use to estimate water level variations in the lakes. The validated runoff coefficients were also applied to Dolphin Lake catchments. Runoff coefficients are summarized in Table A-3.

The runoff coefficients seem low because there was no detailed data available to accurately quantify water withdrawals and outflows, however they did represent a good fit to the data that was available.

The post-development runoff coefficients were developed by assuming a runoff coefficient of 1.0 for all future impervious areas and the pre-development runoff coefficients for all other areas. The values were area weighted to determine an average runoff coefficient.

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**Table A-3: Runoff Coefficients**

| Month | Runoff Coefficients | | Month | Runoff Coefficients | |
|---|---|---|---|---|---|
| | Validated Existing Conditions | Post-development | | Validated Existing Conditions | Post-development |
| Jan | 0.4 | 0.5 | Jul | 0.1 | 0.3 |
| Feb | 0.3 | 0.4 | Aug | 0.1 | 0.3 |
| Mar | 0.3 | 0.4 | Sep | 0.2 | 0.3 |
| Apr | 0.2 | 0.3 | Oct | 0.2 | 0.3 |
| May | 0.2 | 0.3 | Nov | 0.2 | 0.3 |
| Jun | 0.1 | 0.3 | Dec | 0.2 | 0.3 |

## Continuous Simulation Modelling

To process and find meaningful results from such a large data set of results, the cumulative distribution of the water levels were summarized into water level exceedance duration curves. Exceedance duration curves generally show a comparison between the amount of days any given water level occurs for pre- and post-development. The post-development curves show higher water levels for longer durations than pre-development conditions due to the additional runoff generated in the tributary catchment. The water level exceedance duration curves for Enos and Dolphin Lakes are shown in Figures A-1 and A-2.

## Enos Lake Water Level Impacts

The impacts of development on Enos Lake include higher water levels and longer durations for any given water level. Figure 9 shows the pre- and post-development water levels and Figure A-1 shows the pre- and post-development exceedance duration curves for the lake.

The maximum peak water level increase is approximately 7 cm higher in the post-development scenario. With this increased depth of water the surface lake area would be expanded approximately 0.11 ha based on the surrounding contours. The increased duration of any given water level generally ranges from 1 to 2 times higher during post-development (i.e. any given water level above the outlet weir occurs more frequently post-development than during pre-development).

In June, July, and August, when pumping removes water from the lake, the post-development water level does not decrease to a given depth below the outlet as often as pre-development. Assuming pump rates remain similar to current rates, the summer water levels in the lake will be consistently higher post-development.

Comparing the model results with recorded lake water levels record shows that a water level rise of 40-50 cm above the outlet weir is consistent with observations.

# Appendix A

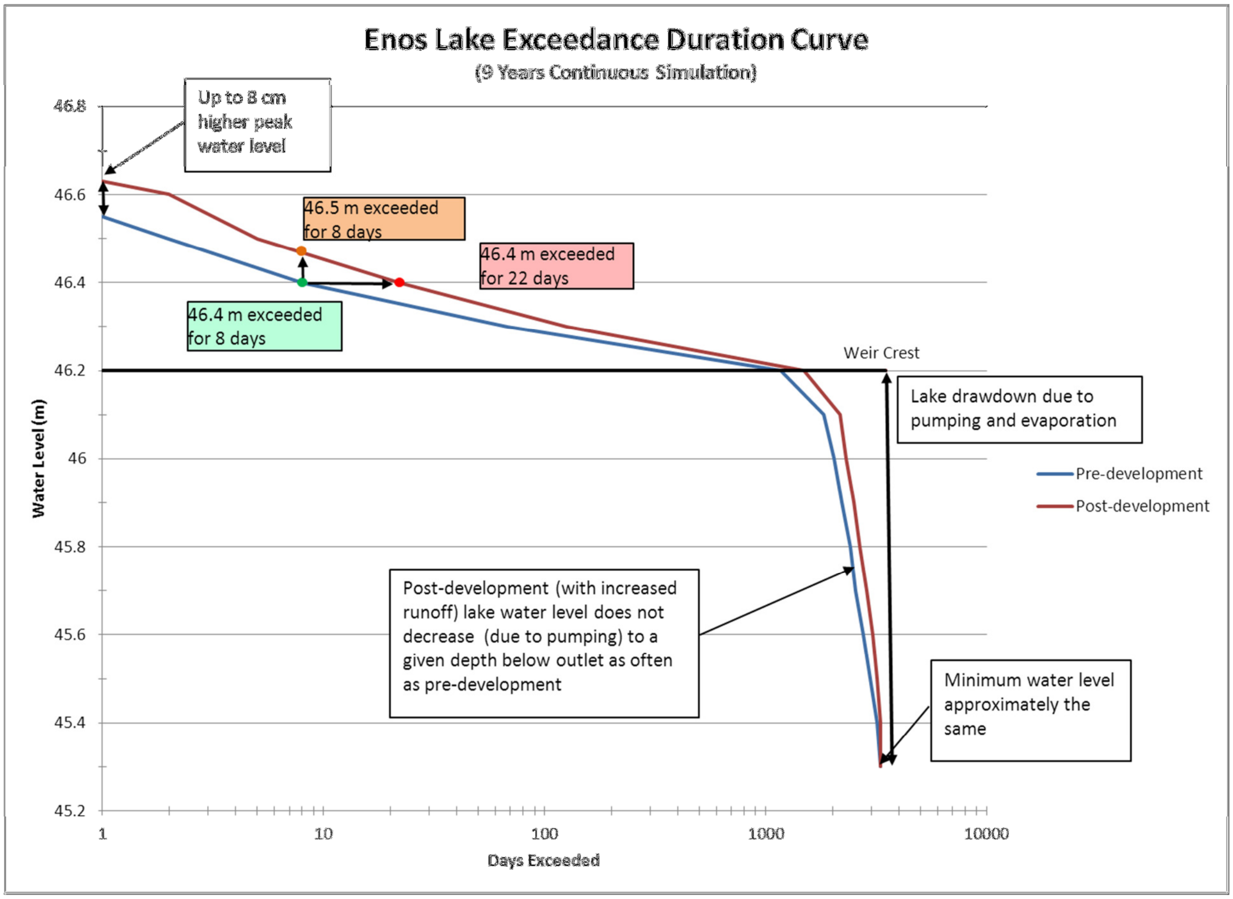


**Figure A-1 – Enos Lake Water Level Exceedance Duration Curves**

When the 17% climate change factor is added to the rain, the peak water levels increase in both the pre-and post-development by approximately 7 cm. The difference in peak water levels between pre- and post-development is approximately the same with and without climate change. The duration of exceedance of a given water level increases with climate change. The duration at any given water level for the pre-development with climate change scenario is approximately 1 to 2 times the duration of the pre-development without climate change scenario. Durations for the post development with climate change are 1 to 2 times longer than the pre-development with climate change.

## Dolphin Lake Level Impacts

The impacts of the proposed development on Dolphin Lake include higher water levels and longer durations at given water levels. Figure 10 shows the pre- and post-development water levels and Figure A2 shows the pre- and post-development exceedance duration curves for the lake.

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The maximum peak water level increase is approximately 7 cm higher in the post-development scenario which results in an additional 0.1 ha of lake surface area. The increased duration of given water levels generally ranges from 1 to 3 times higher during post-development - any given water level above the outlet occurs more frequently in the post-development than the pre-development.

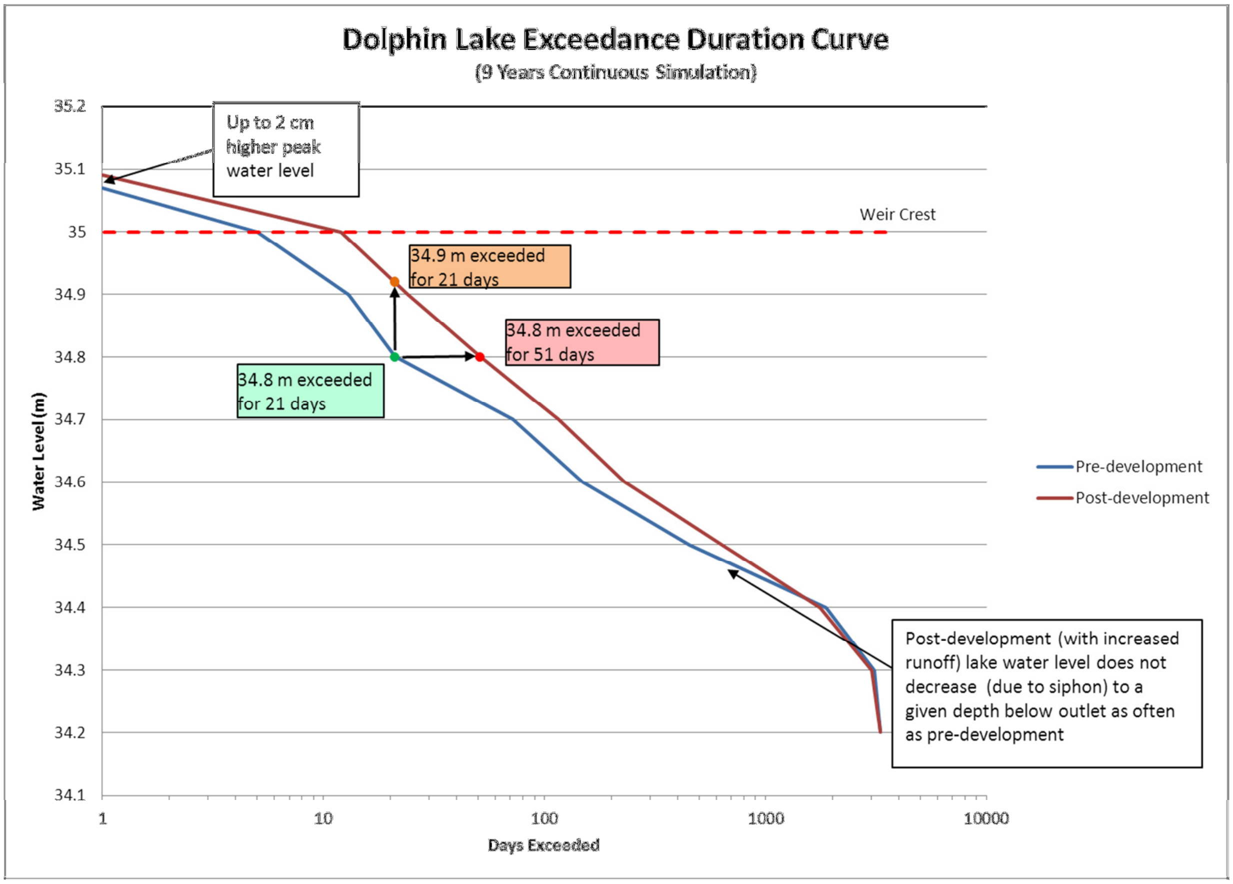


**Figure A-2 – Dolphin Lake Water Level Exceedance Duration Curves**

When the 17% climate change factor is added to the rain, the peak water levels increase in the pre-development by 6 cm and in the post-development by 11 cm, while the difference in maximum peak water levels between pre- and post-development is approximately the same with and without climate change. The duration of water levels increases with climate change. The duration at any given water level for the pre-development with climate change scenario is approximately 1 to 3 times the duration of the pre-development without climate change scenario. Durations for the post development with climate change are 1 to 3 times longer than the pre-development with climate change.

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## A.4 Continuous Simulation Modelling of Wetlands

The previously-developed SWMM model was modified to include only areas upstream of the nine wetlands. This modified model was run using the nine years of rainfall data that was used in the continuous lake water balance modelling (see Section A.3). Pre-development and post-development scenarios were simulated to assess the impacts of development and to identify the mitigation works required to protect each wetland.

The inflow and water level exceedance duration curves for the nine wetlands in the study area are summarized below.

### Wetland W1

During the nine years of continuous modelling there is a minimal difference in peak inflow into the wetland between pre- and post-development scenarios (see Figure A-3). The minimal change is largely due to the 3% increase in catchment area to the wetland between the pre- and post-development scenarios. There is also a large increase in the wetland catchment TIA of 43% between the pre- and post-development scenarios. There is an imperceptible difference in the water level exceedance duration as shown in Figure A-4.

It is recommended that the developed areas in the catchment that drains directly to the wetland (downstream of Enos Lake) be detained using a 2,300 $m^3$ detention volume. A WQ treatment and detention facility is proposed to treat the runoff from roads that will not have roadside rain gardens and detain the flows from the 23 ha catchment downstream of Enos Lake prior to discharge to the wetland. To detain the post-development flows from the catchment upstream of Enos Lake, modify the outlet weir (after further flow and water level data is collected and analysis is performed).

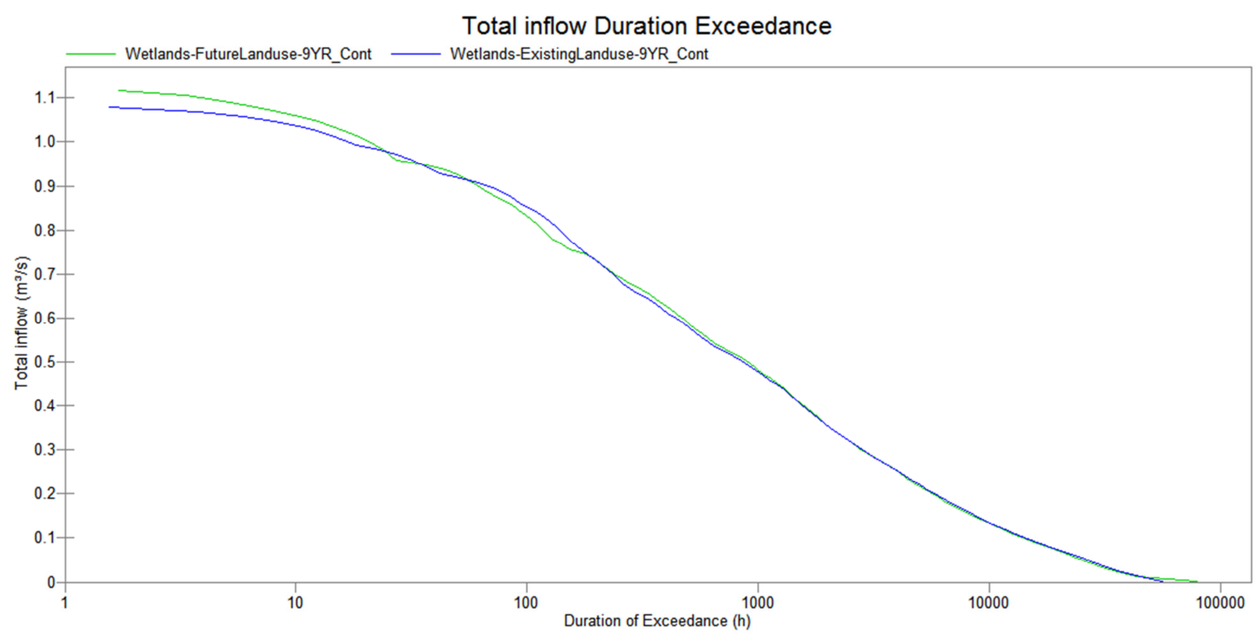


**Figure A-3 – Wetland W1 Inflow Exceedance Duration Curve**

# Appendix A

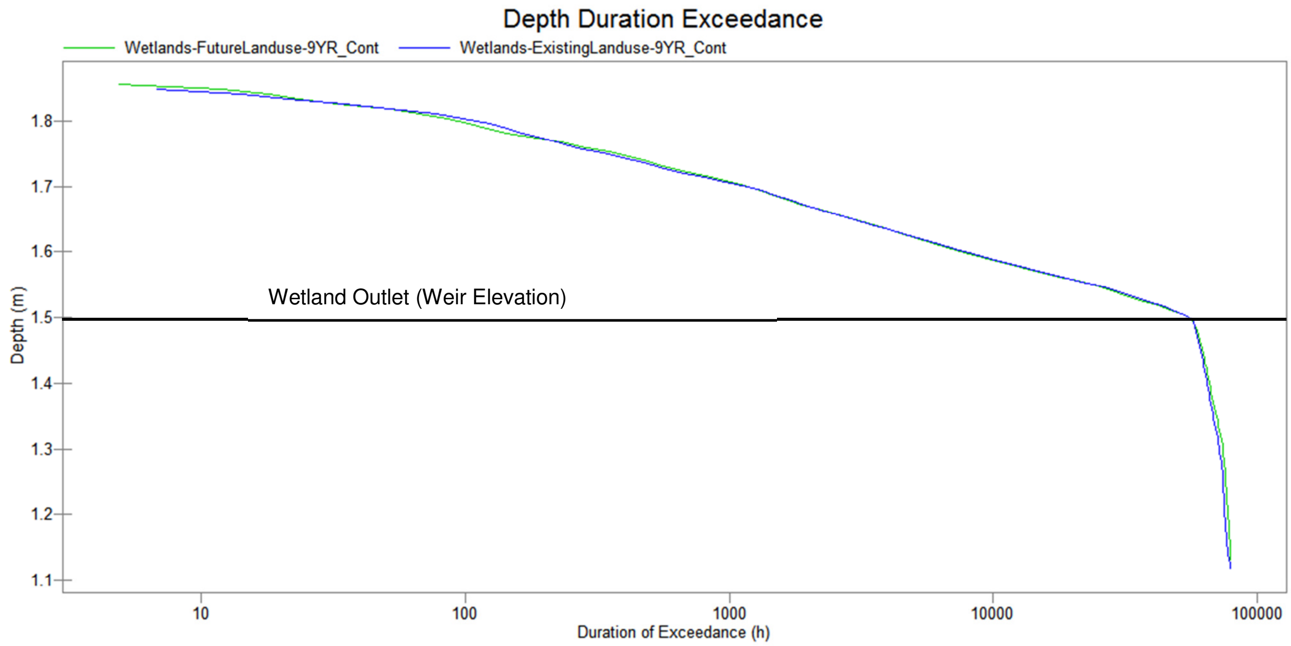


**Figure A-4 – Wetland W1 Water Level Exceedance Duration Curve**

## Wetland W2

During the nine years of continuous modelling the exceedance duration graph shows that any given flow occurs for a longer duration and slightly higher peak flows in the post-development scenario (see Figure A-5). This is due to a 10% increase in catchment area to the wetland between the pre- and post-development scenarios. There is also a large increase in the wetland catchment TIA of 54% between the pre- and post-development scenarios. There is an imperceptible difference in the water level exceedance duration as shown in Figure A-6.

It is recommended that the outlet of this wetland be modified to provide the required 1,400 $m^3$ of detention volume, allowing the 5-year peak water level to rise by approximately 14 cm.

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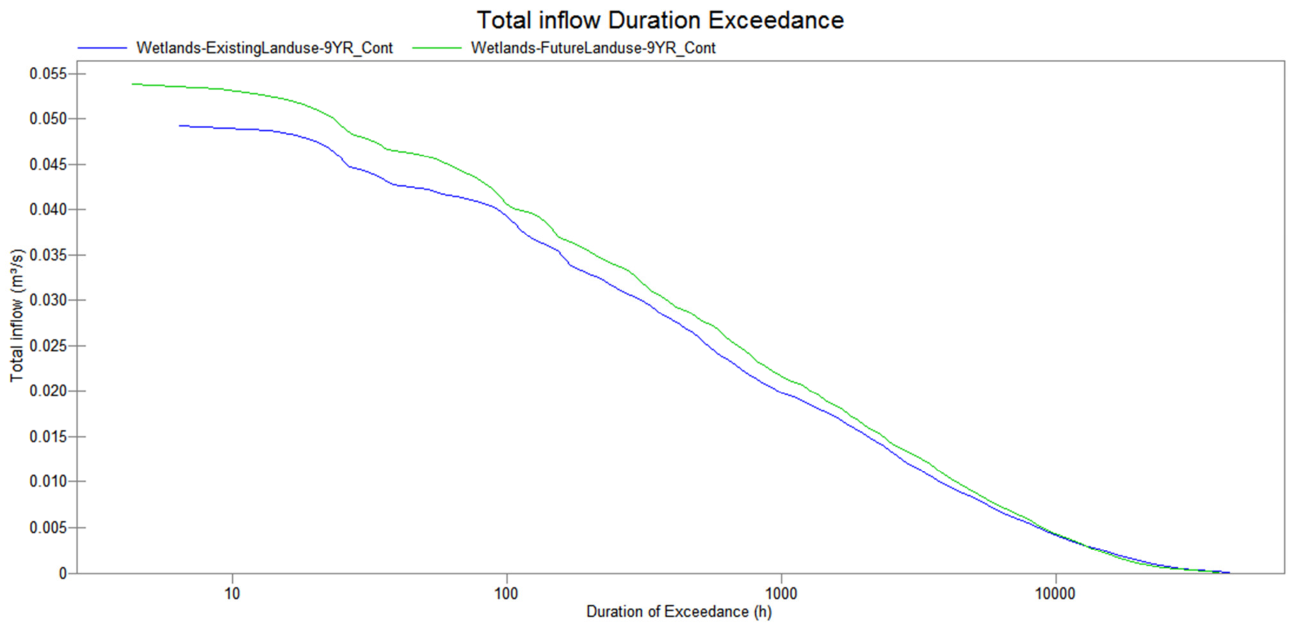


**Figure A-5 – Wetland W2 Inflow Exceedance Duration Curve**

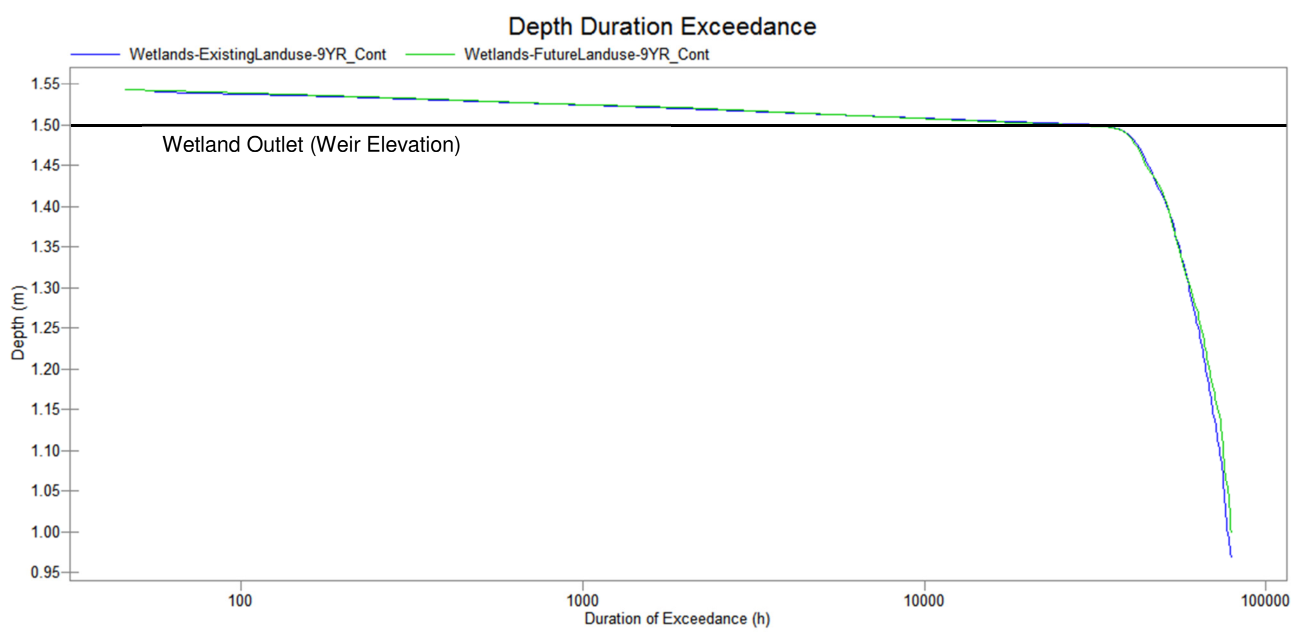


**Figure A-6 – Wetland W2 Water Level Exceedance Duration Curve**

# Appendix A

## Wetland W3

During the nine years of continuous modelling the exceedance duration graph shows that any given flow occurs for a much longer duration and higher peak flows in the post-development scenario (see Figure A-7). This is due to a 95% increase in catchment area to the wetland between the pre- and post-development scenarios. There is also a large increase in the wetland catchment TIA of 50% between the pre- and post-development scenarios. There is a difference in the water level exceedance duration especially when the water level is below the outlet elevation due to increased inflows into the wetland in the summer months as shown in Figure A-8.

It is recommended that a flow splitter be utilized to send base flows to the wetland to maintain current water levels while diverting high flows to Enos Lake.

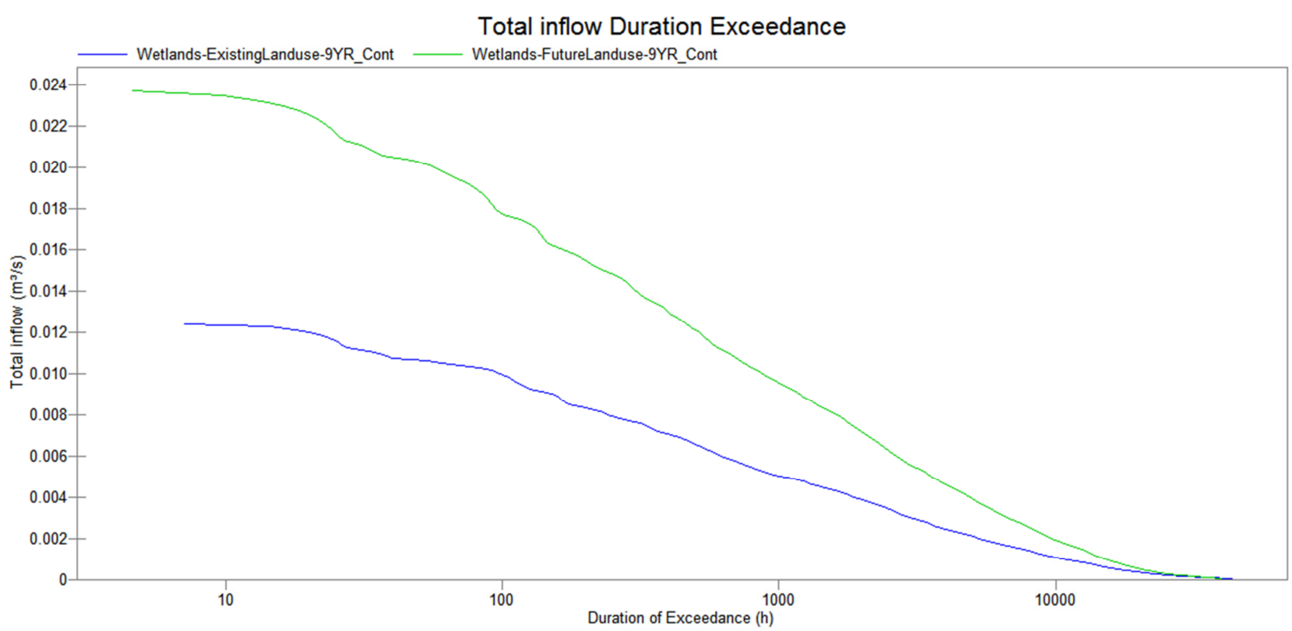


**Figure A-7 – Wetland W3 Inflow Exceedance Duration Curve**

# Appendix A

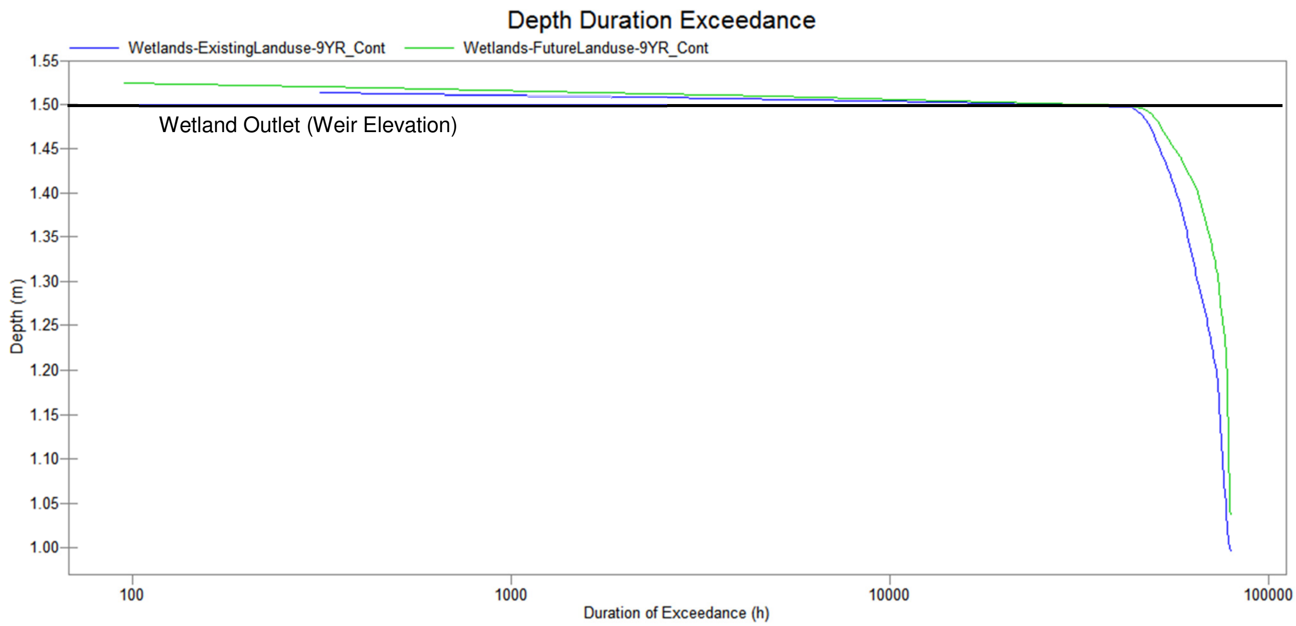


**Figure A-8 – Wetland W3 Water Level Exceedance Duration Curve**

## Wetland W4

During the nine years of continuous modelling the exceedance duration graph shows that any given flow occurs for a shorter duration and slightly lower peak flows in the post-development scenario (see Figure A-9). This is due to a 14% decrease in catchment area to the wetland between the pre- and post-development scenarios. There is an increase in the wetland catchment TIA of 6% between the pre- and post-development scenarios. The water level exceedance duration shows lower post-development water levels and shorter durations of a given water level due to decreased inflows into the wetland as shown in Figure A-10.

It is recommended that the outlet of this wetland be modified to provide the required 3,900 $m^3$ of detention volume, allowing the 5-year peak water level to rise by approximately 16 cm.

# Appendix A

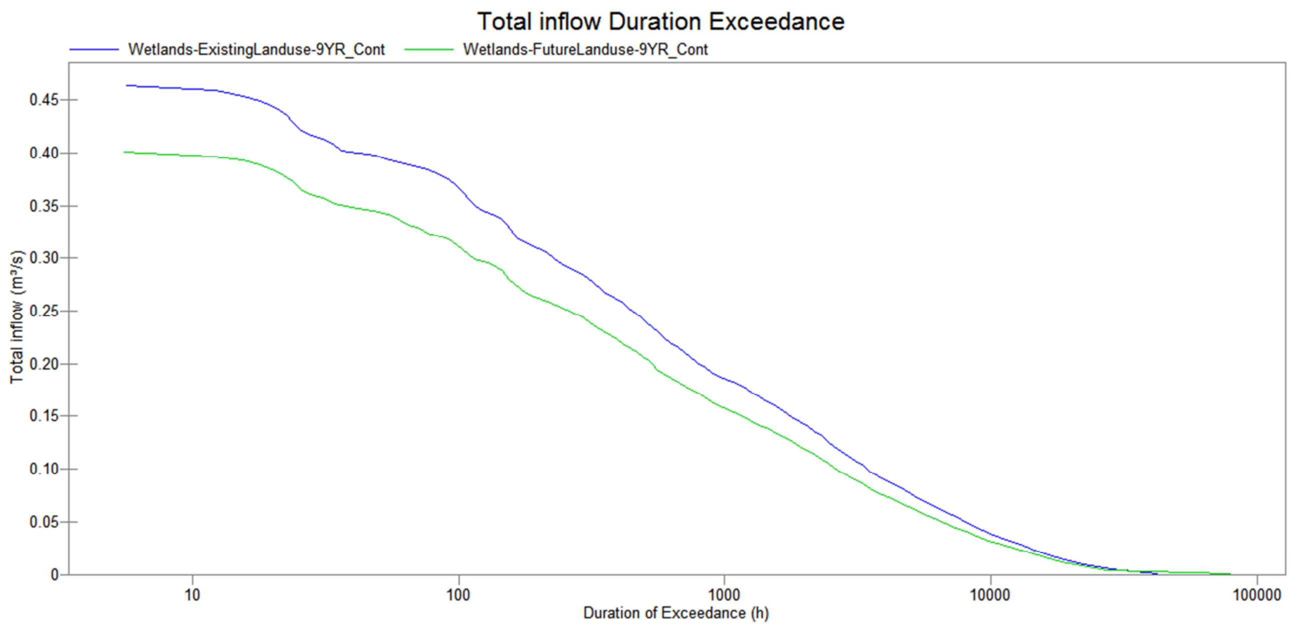


**Figure A-9 – Wetland W4 Inflow Exceedance Duration Curve**

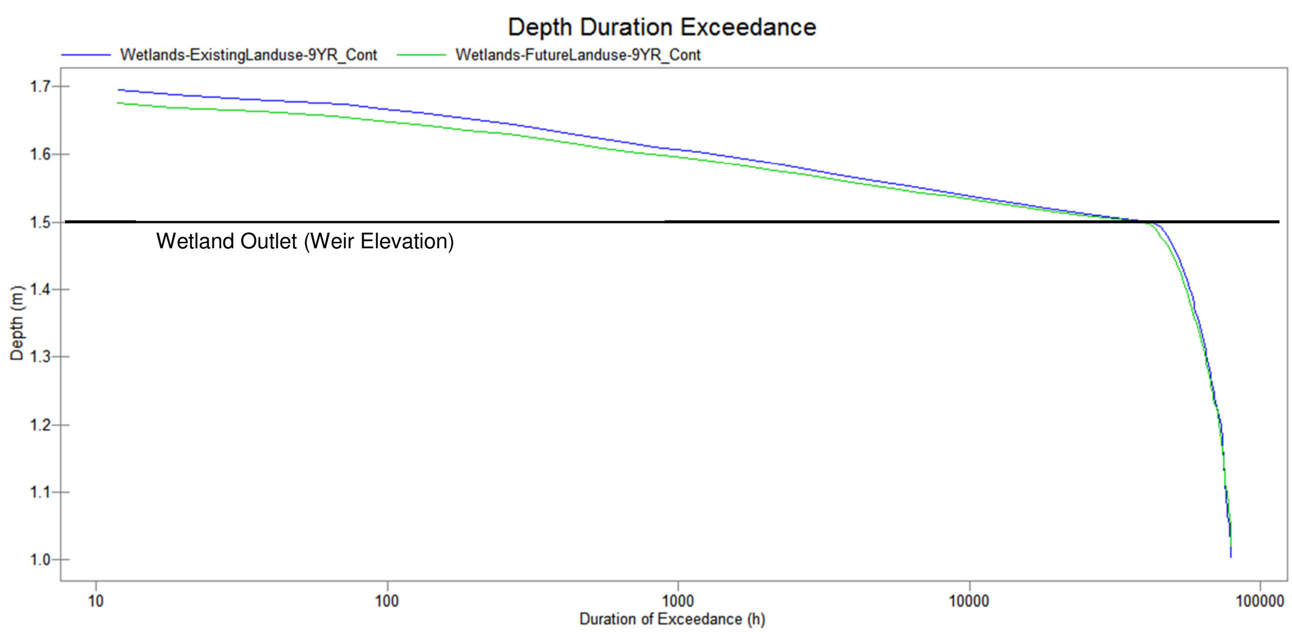


**Figure A-10 – Wetland W4 Water Level Exceedance Duration Curve**

# Appendix A

## Wetland W5

During the nine years of continuous modelling the exceedance duration graph shows that any given flow occurs for a much shorter duration and much lower peak flows in the post-development scenario (see Figure A-11). This is due to a large 75% decrease in catchment area to the wetland between the pre- and post-development scenarios. There is an increase in the wetland catchment TIA of 18% between the pre- and post-development scenarios. The water level exceedance duration shows lower post-development water levels and shorter durations of a given water level due to decreased inflows into the wetland as shown in Figure A-12.

It is recommended that baseflows from outside of the wetland's post-development catchment be directed to the wetland to maintain current water levels.

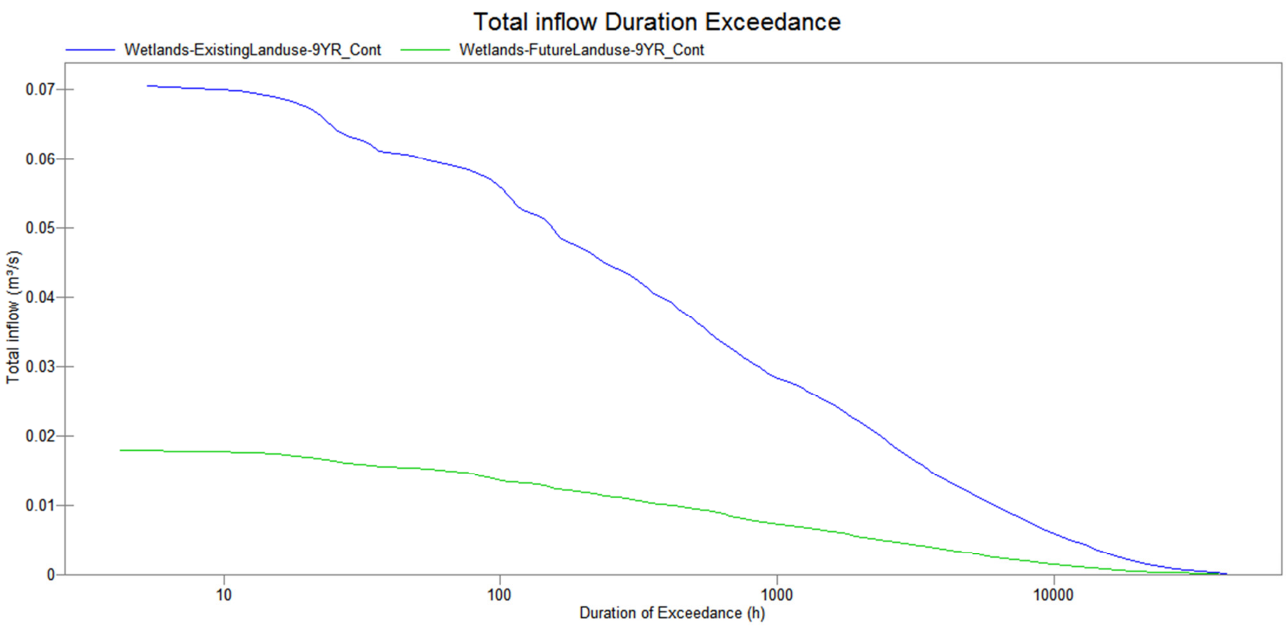


**Figure A-11 – Wetland W5 Inflow Exceedance Duration Curve**

# Appendix A

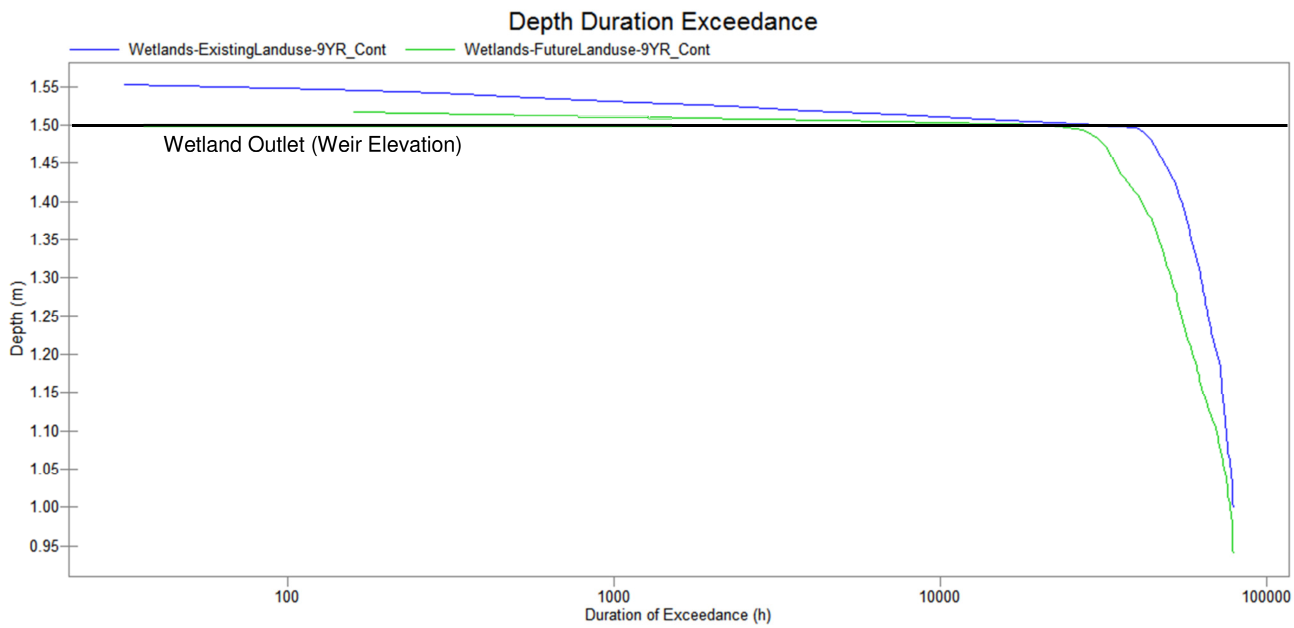


**Figure A-12 – Wetland W5 Water Level Exceedance Duration Curve**

## Wetland W6

During the nine years of continuous modelling the exceedance duration graph shows that any given flow occurs for a longer duration and slightly higher peak flows in the post-development scenario (see Figure A-13). This is due to a 6% increase in catchment area to the wetland between the pre- and post-development scenarios. There is also an increase in the wetland catchment TIA of 7% between the pre- and post-development scenarios. There is an imperceptible difference in the water level exceedance duration as shown in Figure A-14.

It is recommended that a flow splitter be utilized to send base flows to the wetland to maintain current water levels while diverting high flows to Enos Lake.

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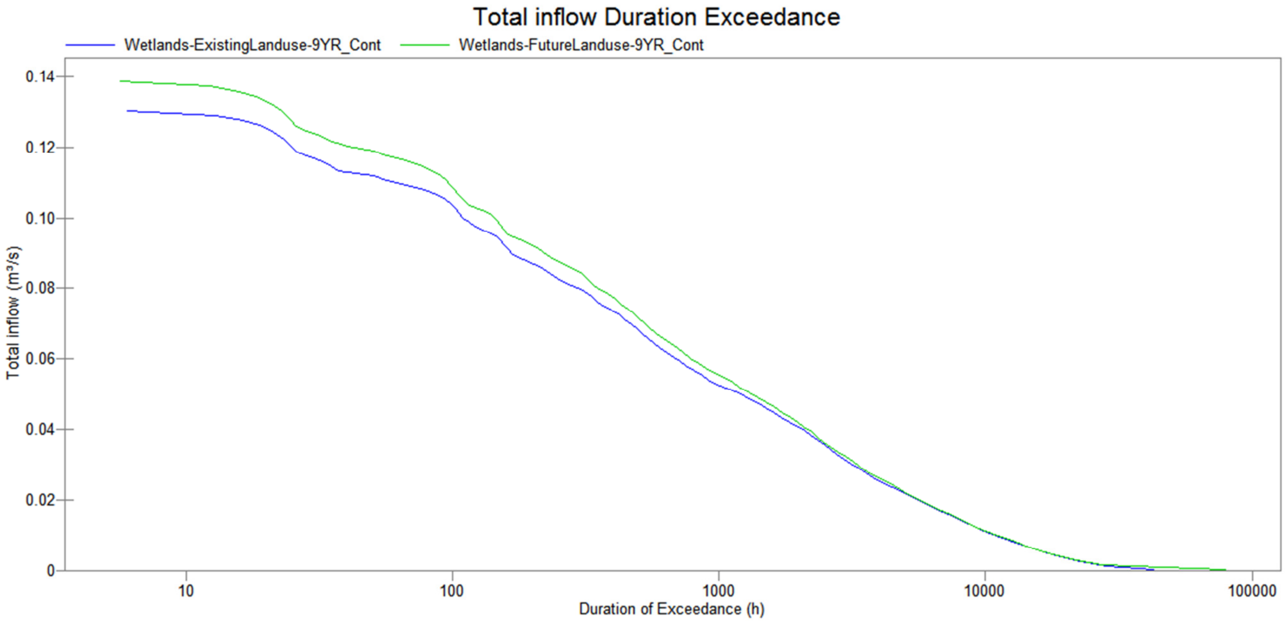


**Figure A-13 – Wetland W6 Inflow Exceedance Duration Curve**

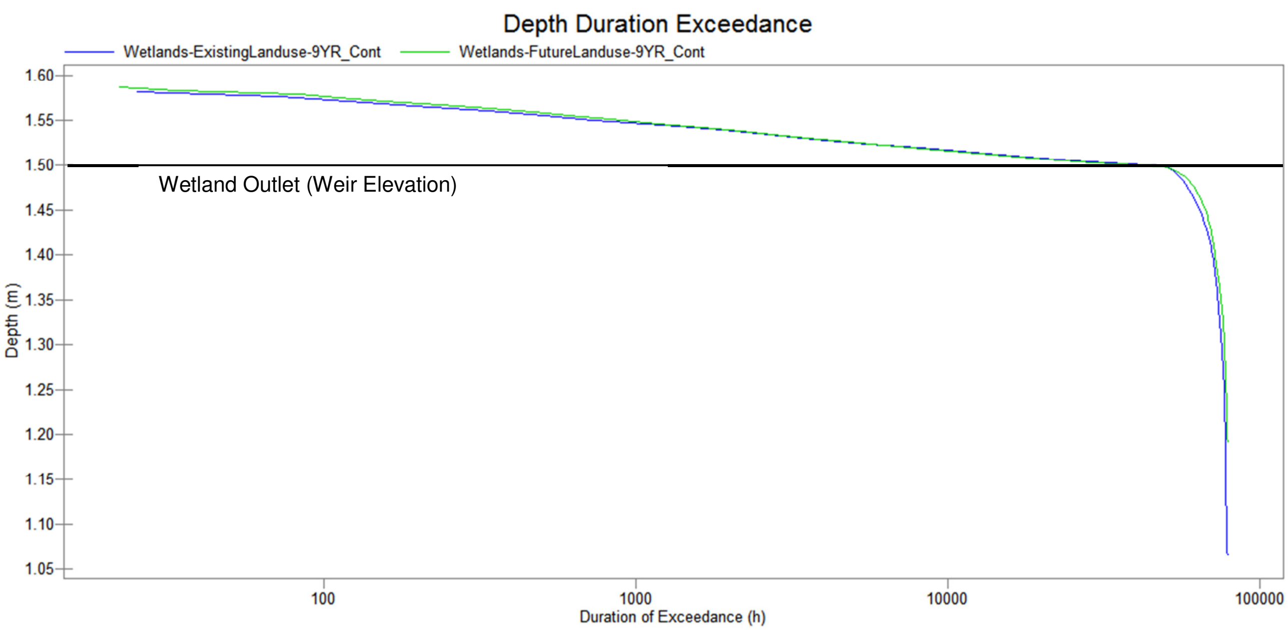


**Figure A-14 – Wetland W6 Water Level Exceedance Duration Curve**

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## Wetland W7

During the nine years of continuous modelling the exceedance duration graph shows that any given flow occurs for a longer duration and higher peak flows in the post-development scenario (see Figure A-15). This is due to an 18% increase in catchment area to the wetland between the pre- and post-development scenarios. There is also an increase in the wetland catchment TIA of 15% between the pre- and post-development scenarios. There is a small difference in the water level exceedance duration due to increased inflows into the wetland as shown in Figure A-16.

It is recommended that the existing detention ponds upstream of the wetland be expanded to provide the required 4,850 $m^3$ detention volume to prevent negative impacts to the wetland.

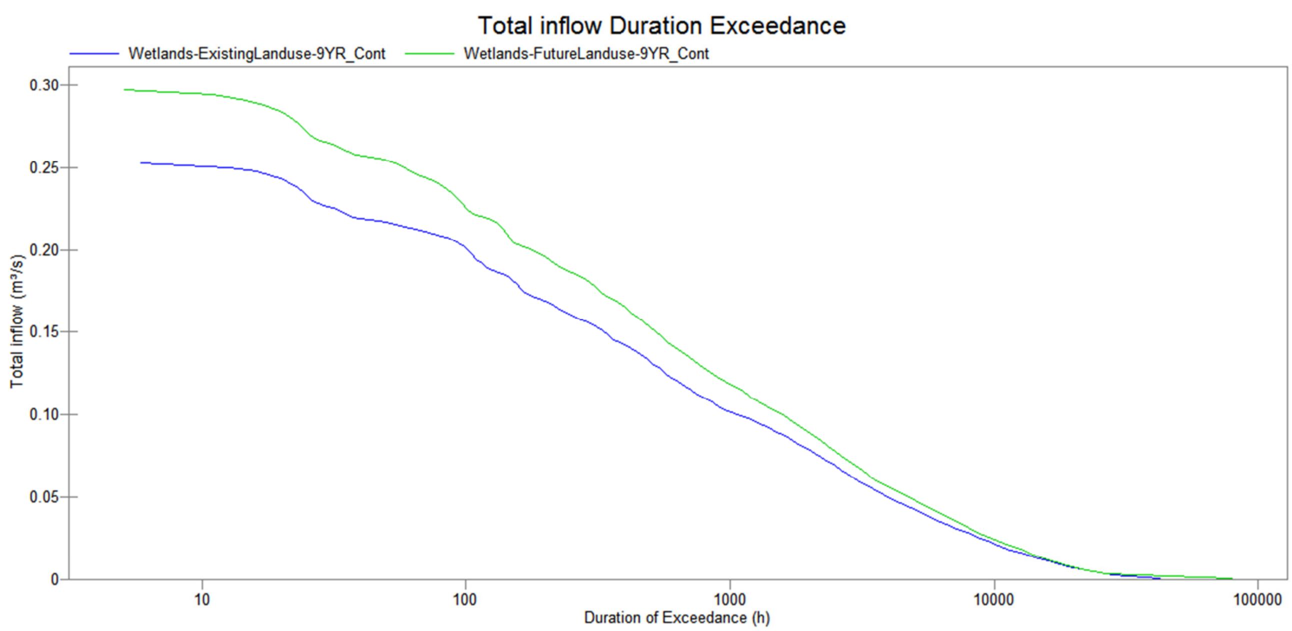


**Figure A-15 – Wetland W7 Inflow Exceedance Duration Curve**

# Appendix A

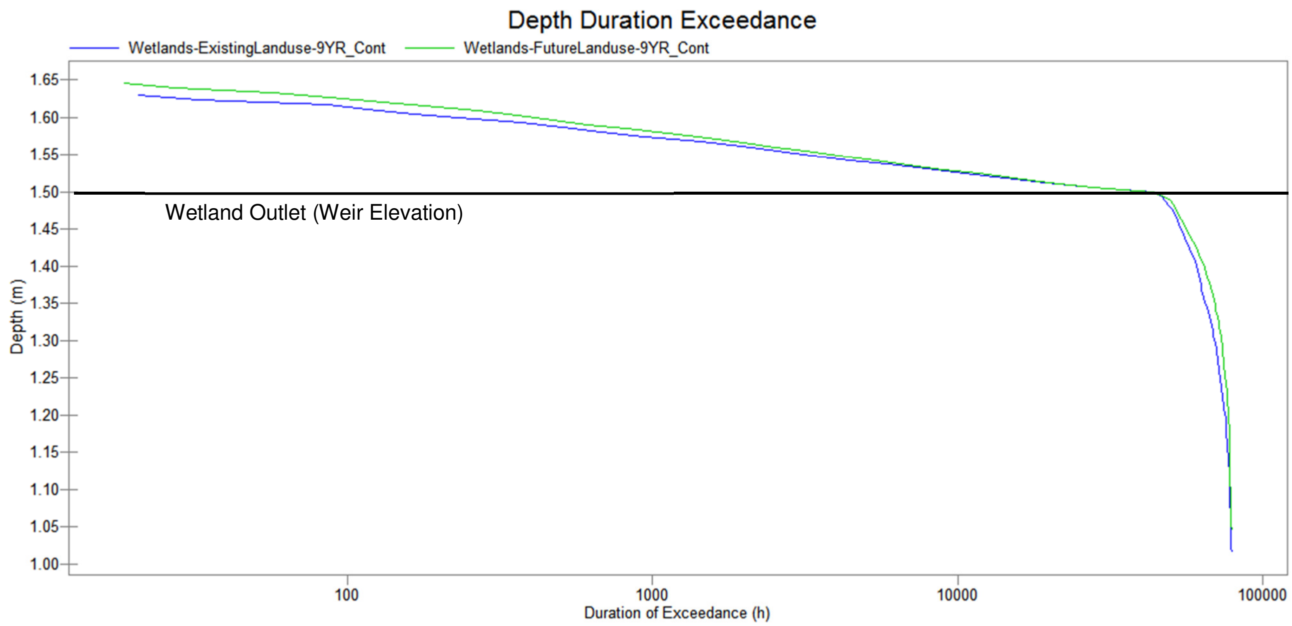


**Figure A-16 – Wetland W7 Water Level Exceedance Duration Curve**

## Wetland W8

During the nine years of continuous modelling the exceedance duration graph shows that any given flow occurs for a much longer duration and higher peak flows in the post-development scenario (see Figure A-17). This is due to a 108% increase in catchment area to the wetland between the pre- and post-development scenarios. There is also a large increase in the wetland catchment TIA of 38% between the pre- and post-development scenarios. There is a difference in the water level exceedance duration especially when the water level is below the outlet elevation due to increased inflows into the wetland in the summer months as shown in Figure A-18.

It is recommended that the catchment runoff be detained using a 360 $m^3$ detention volume. A WQ treatment and detention facility is proposed to treat the runoff from roads that will not have roadside rain gardens and detain the flows from the 0.83 ha catchment prior to discharge to the wetland.

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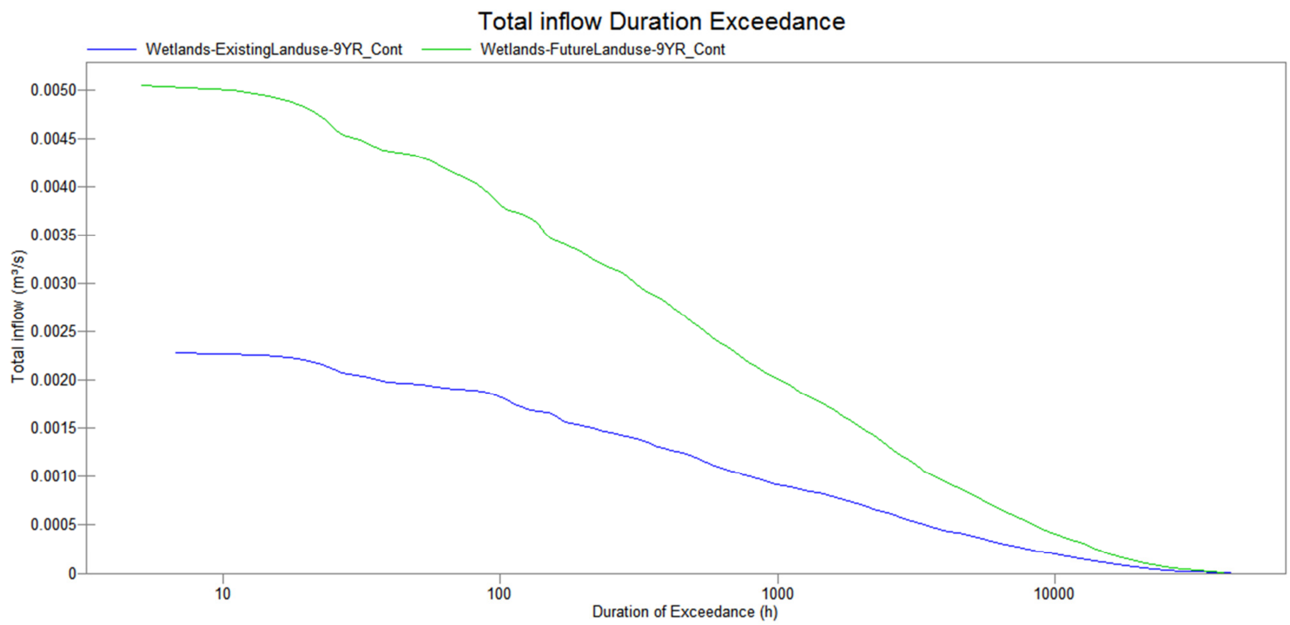


**Figure A-17 – Wetland W8 Inflow Exceedance Duration Curve**

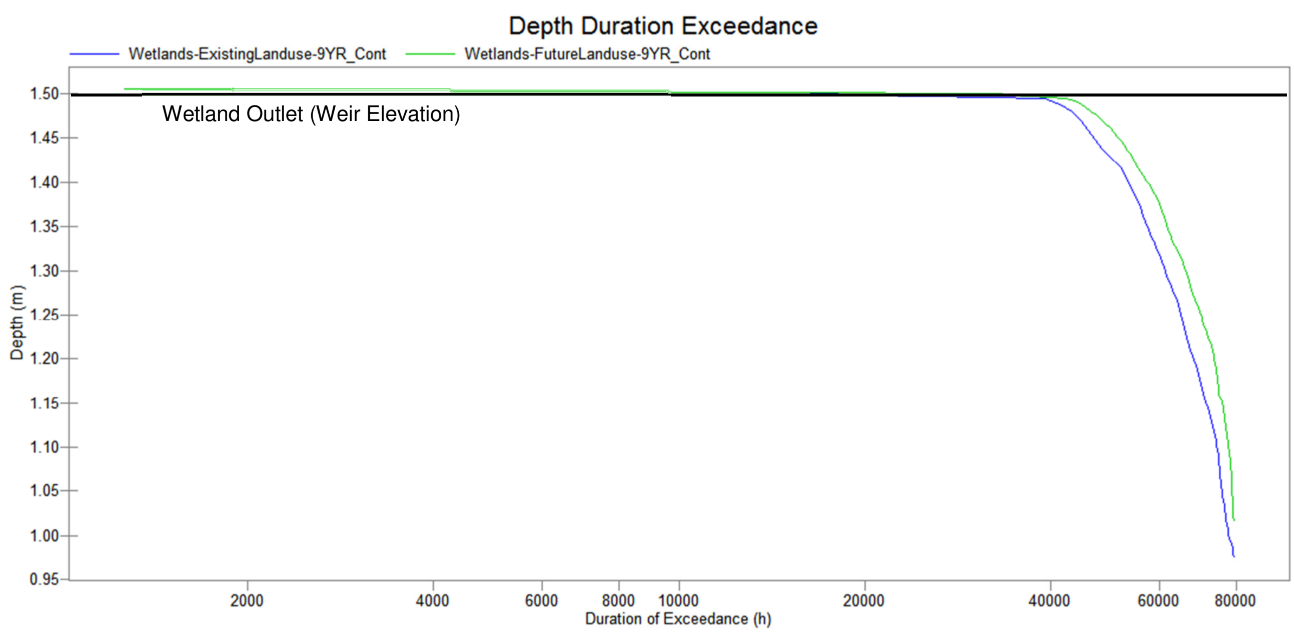


**Figure A-18 – Wetland W8 Water Level Exceedance Duration Curve**

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## Wetland W9

During the nine years of continuous modelling there is an imperceptible difference in peak inflows or flow durations into the wetland between pre- and post-development scenarios (see Figure A-19). This is due to the catchment area to the wetland remaining unchanged between the pre- and post-development scenarios. There is an increase in the wetland catchment TIA of 17% between the pre- and post-development scenarios.

It is recommended that the outlet of this wetland be modified to provide the required 280 $m^3$ of detention volume, allowing the 5-year peak water level to rise by approximately 6 cm.

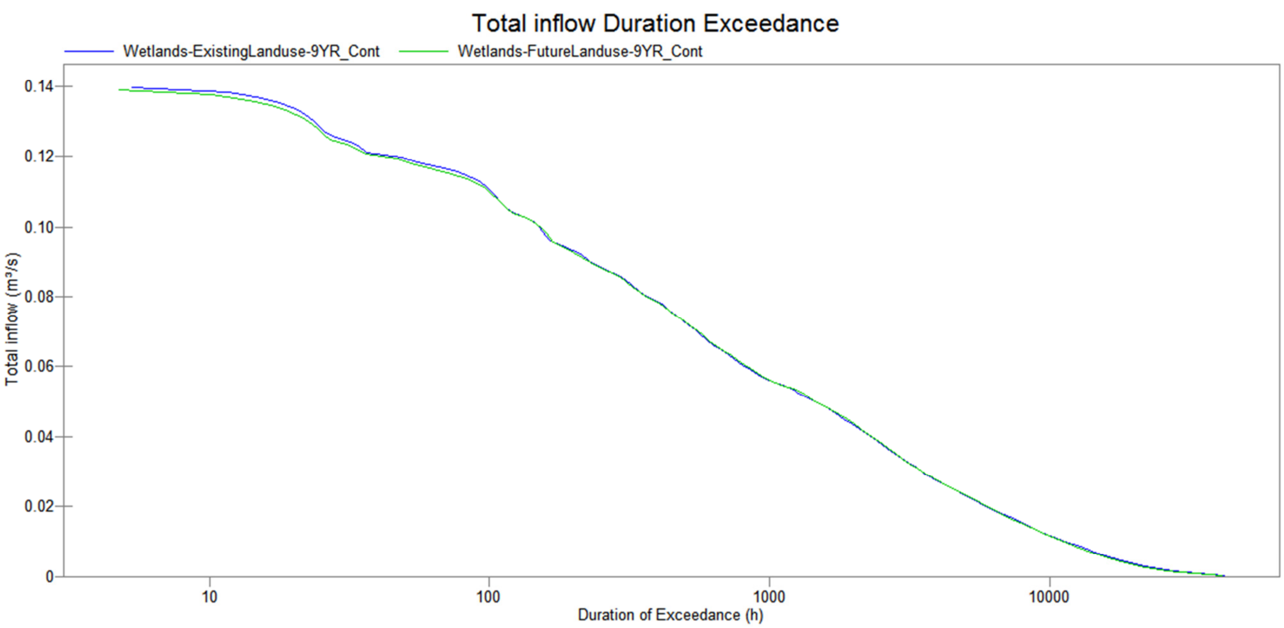


**Figure A-19 – Wetland W9 Inflow Exceedance Duration Curve**

# Appendix A

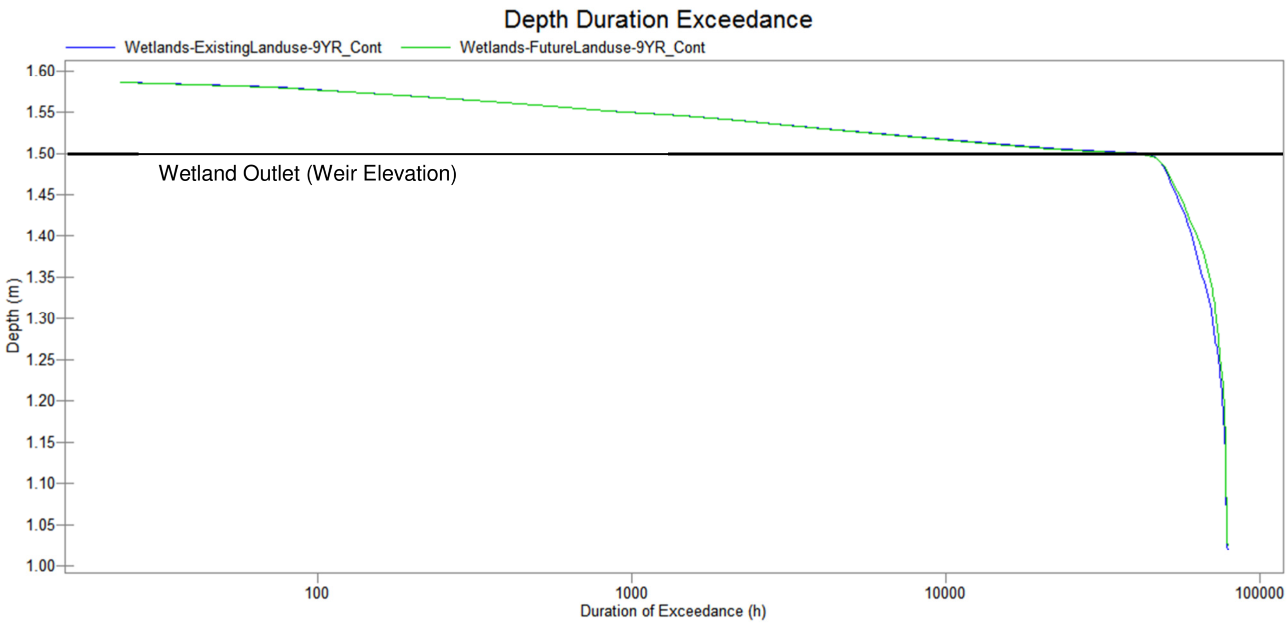


**Figure A-20 – Wetland W9 Water Level Exceedance Duration Curve**

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KERR WOOD LEIDAL
consulting engineers

## Appendix B

# AquaTerra 2013
# Enos Lake Water Quality Monitoring Report

# MEMORANDUM

**TO:** David Scott
3455 Fairwinds Drive
Nanoose Bay, B.C.
V9P 9K6

**FROM:** Chris Lee, **M.Sc., RPBio., QEP, BC-CESCL**

**Date:** 10 May 2013

**RE: Early Spring 2013 Enos Lake Water Quality Monitoring Results**

## Overview

AquaTerra Environmental Ltd. ('AquaTerra') is pleased to provide Fairwinds Community & Resort ('Fairwinds') with this memorandum, which summarizes the Early Spring 2013 Enos Lake and Enos Lake wetland (situated in Nanoose Bay, BC; **Figure 1**) water quality monitoring results. Additionally, this memorandum compares the Early Spring 2013 results and historical analytical results collected periodically since Fall 2006 to evaluate temporal changes, if any.

**Figure 1:** Project Location Details


## Purpose

The primary purpose of this memorandum is to provide Fairwinds with a comprehensive summary of physicochemical[1] water quality field measurements and laboratory analyzed water quality results from water samples collected within Enos Lake and the adjacent Enos Lake wetland[2] on 01 March 2013. The memorandum also contains a brief discussion and interpretation of the field and laboratory results and compares the current dataset to historical results to evaluate and monitor trends, if any, over time.

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[1] pH, Temperature, Conductivity, Oxidation-Reduction Potential [ORP], Percent Oxygen and Oxygen Concentration
[2] both waterbodies are located on the Fairwinds property

Of note, this marks the first monitoring event in which a water sample was collected using a Kemmerer sampler from a deeper portion of the lake (SWMP-03) as suggested by the BC Ministry of Environment (MoE; now the BC Ministry of Forests, Lands and Natural Resource Operations [MFLNRO]) following their review of the existing monitoring program and associated results to-date.

Summary of Sampling Activities

On 01 March 2013, Mr. Chris Lee of AquaTerra and Mr. Dave Scott of Fairwinds collected surface water samples for laboratory analysis at five (5)[3] sampling locations (SWMP-01, SWMP-03, SWMP-04, SWMP-06, and WET-01) and one deep water sample at SWMP-03D (Deep). Physicochemical water quality parameters were measured at six sampling locations (SWMP-01 to SWMP-06 and WET-01) at varying pre-determined depths using a YSI 600XLM probe and 15 meters of cable. The sampling locations mirrored those from previous water quality sampling events (confirmed in the field via hand-held GPS), which are outlined in **Table 1**.

**Table 1:** Sample Identification, Approximate Sampling Locations and GPS Coordinates

| Sample ID | Approximate Location | GPS Location[4] |
|---|---|---|
| SWMP-01 | Southern portion of Enos Lake | 0416252 E<br>5458943 N |
| SWMP-02 | Approximately 40 metres southwest of the raised marsh area | 0415993 E<br>5459113 N |
| SWMP-03 | Approximately 300 metres north of the raised marsh area | 0415803 E<br>5459374 N |
| SWMP-04 | North edge of Enos Lake, proximate to the dam and service road | 0415497 E<br>5459797 N |
| SWMP-05 | Southeast edge of the deep portion of Enos Lake | 0415628 E<br>5459598 N |
| SWMP-06 | Southernmost tip of lake, proximate to drainage feature discharge location from Enos Lake wetland | 0416425 E<br>5458804 N |
| WET-01 | Enos Lake Wetland area 10 m west of Fairwinds Drive proximate to storm culvert outfall | 0416692 E<br>5458607 N |

**Table 2** summarizes the physicochemical water quality parameters collected in the field using the YSI 600XLM multi-parameter probe, which were recorded at pre-determined depths given that the probe was mounted to the end of the cable. Historically, field measurements, by others, were collected using a combination of hand-held meters and an oxygen meter. As a result,

[3] Water samples were not collected from SWMP-02 as it was concluded in the Fall 2008 monitoring report that this location provided limited information relative to the other sampling locations.
[4] UTM 10 – NAD 83 (Canada)

measurements collected prior to 2008 were limited to the surface with the exception of temperature, percent oxygen and oxygen concentration.

**Table 2:** Enos Lake Sampling Locations and Corresponding Spring 2013 Field Measurements

| Sample Location | Depth | Temp. | pH[5] | Conductivity[6] | ORP[7] | Percent Oxygen | Oxygen Conc. | TDS[8] |
|---|---|---|---|---|---|---|---|---|
| Units | m | °C | pH units | µS/cm | mV | % | mg/L | g/L |
| SWMP-01 | Surface | 5.72 | 7.41 | 89 | 109.2 | 91.8 | 11.52 | 0.086 |
| SWMP-01 | 1.1 | 5.63 | 7.44 | 86 | 109.4 | 91.1 | 11.44 | 0.086 |
| SWMP-02 | Surface | 5.55 | 7.45 | 88 | 108.8 | 91.9 | 11.57 | 0.088 |
| SWMP-02 | 1.1 | 5.52 | 7.47 | 88 | 108.1 | 91.7 | 11.56 | 0.088 |
| SWMP-02 | Bottom[a] (1.9) | 5.49 | 7.49 | 88 | 107.8 | 90.6 | 11.43 | 0.087 |
| SWMP-03 | Surface | 5.49 | 7.43 | 84 | 94.7 | 93.4 | 11.77 | 0.087 |
| SWMP-03 | 1.1 | 5.47 | 7.51 | 84 | 94.9 | 92.8 | 11.72 | 0.087 |
| SWMP-03 | 1.9 | 5.45 | 7.51 | 84 | 95.3 | 92.7 | 11.70 | 0.087 |
| SWMP-03 | 3.1 | 5.43 | 7.48 | 84 | 96.6 | 92.6 | 11.68 | 0.087 |
| SWMP-03 | 4.5 | 5.40 | 7.40 | 84 | 102.2 | 92.5 | 11.69 | 0.087 |
| SWMP-03 | 6.1 | 5.39 | 7.56 | 84 | 98.9 | 92.0 | 11.63 | 0.087 |
| SWMP-03 | 7.6 | 5.38 | 7.55 | 83 | 98.6 | 91.6 | 11.59 | 0.086 |
| SWMP-03 | 8.9 | 5.38 | 7.45 | 82 | 102.0 | 91.7 | 11.60 | 0.086 |
| SWMP-03 | 11.1 | 5.38 | 7.49 | 82 | 103.0 | 91.2 | 11.53 | 0.086 |
| SWMP-03 | Bottom (12.3) | 5.38 | 7.53 | 83 | 100.5 | 81.5 | 10.30 | 0.086 |
| SWMP-04 | Surface | 5.56 | 7.44 | 83 | 102.3 | 107.1 | 13.47 | 0.085 |
| SWMP-04 | 1.1 | 5.56 | 7.47 | 83 | 101.1 | 104.2 | 13.12 | 0.085 |
| SWMP-04 | Bottom (1.9) | 5.50 | 7.50 | 82 | 103.4 | 100.4 | 12.65 | 0.085 |
| SWMP-05 | Surface | 5.50 | 7.46 | 85 | 110.5 | 94.9 | 11.97 | 0.088 |
| SWMP-05 | 1.1 | 5.49 | 7.50 | 85 | 109.0 | 94.2 | 11.89 | 0.088 |
| SWMP-05 | 1.9 | 5.46 | 7.56 | 85 | 105.8 | 94.6 | 11.94 | 0.088 |
| SWMP-05 | 3.1 | 5.42 | 7.50 | 85 | 107.4 | 94.3 | 11.91 | 0.088 |
| SWMP-05 | 4.5 | 5.42 | 7.54 | 85 | 104.7 | 94.2 | 11.90 | 0.088 |
| SWMP-05 | 6.1 | 5.41 | 7.59 | 85 | 104.3 | 93.7 | 11.84 | 0.089 |
| SWMP-05 | 7.6 | 5.41 | 4.60 | 85 | 102.0 | 93.9 | 11.86 | 0.089 |
| SWMP-05 | 8.9 | 5.41 | 7.62 | 85 | 98.6 | 93.2 | 11.78 | 0.088 |
| SWMP-05 | Bottom (11.1) | 5.41 | 7.48 | 85 | 58.0 | 76.7 | 9.80 | 0.088 |
| SWMP-06 | Surface | 7.36 | 7.36 | 85 | 115.9 | 88.3 | 11.07 | 0.088 |

[a] historical geodetic datum survey – greatest depth was 12.4 m. Depth is anticipated to vary contingent on measurement location and season.

Salinity across the lake and at all depths varied from 0.06-0.07 Parts Per Thousand (PPT) at the surface and remained the same at depth. The saline results fall well within the classification of a

[5] **pH** is a measure of the acidity of a solution, in terms of activity of hydrogen ions ($H^+$)
[6] **Conductivity** is a measure of electrical current flow through a solution, which increases nearly linearly with increasing ion concentration
[7] **ORP** (Oxidation-Reduction Potential) is a method to measure oxidation-reduction (REDOX) molecular reactions in an aqueous solution. In REDOX reactions, one substance gives up electrons (becoming oxidized) and another receives them (becoming reduced).
[8] **TDS** (Total Dissolved Solids) is a measure of the combined content of inorganic and organic substances within water – izonized, micrогranular and suspended.

freshwater system (in contrast the next salinity classification is 'oligohaline' in which salinity ranges from 0.5-5 PPT). These results contrast Summer 2012 and Fall 2011, when surface salnity values were generally 0.06 PPT whereas the higher salinity values (up to 0.11 - 0.14 PPT) were associated with the deeper parts of the lake. As such, in early spring, the lake appears to remain well mixed (destratified) – refer to the 'Discussion of Lake Processes' section for additional details.

Surface water averages for pH, conductivity, ORP, Temperature, Percent Oxygen and Oxygen Concentration (2006 – Present) are provided in **Table 3**. Averages for the deeper part of the lake (sampling locations SWMP-03 and SWMP-05) are provided in **Table 4**. As the values provided in **Table 4** are averages of only two (2) deep-water (i.e., >10 m) locations, results should be interpreted with caution.

**Table 3:** Surface Water Averages for pH, conductivity, ORP, Temperature, Percent Oxygen and Oxygen Concentration (2006 – Present)

| Date | Temperature | pH | Conductivity | ORP | % Oxygen | [Oxygen] |
|---|---|---|---|---|---|---|
| Units | °C | pH units | µS/cm | mV | % | mg/L |
| 06-Sep-06 | | 7.82 | | | | |
| 13-Apr-07 | 11.20 | 7.61 | 135.8 | 137.8 | 114.3 | 12.54 |
| 09-Nov-07 | 10.40 | 7.63 | 140 | 183.6 | 93.5 | 10.67 |
| 24-Apr-08 | 11.02 | 7.90 | 138 | 134.8 | 101.6 | 11.21 |
| 20-Oct-09 | 10.89 | 7.85 | 114 | 80.5 | 94.4 | 10.40 |
| 20-Apr-09 | 12.07 | 7.82 | 120 | 106.7 | 124.7 | 13.41 |
| 13-Nov-09 | 8.17 | 7.97 | 106 | 13.6 | 82.9 | 9.78 |
| 03-May-10 | 13.21 | 7.87 | 103 | 85.0 | 160.6 | 16.85 |
| 02-Dec-10 | 4.10 | 7.85 | 88 | 42.3 | 89.5 | 11.69 |
| 09-May-11 | 14.07 | 7.72 | 104 | 33.4 | 100.3 | 10.31 |
| 14-Nov-11 | 6.79 | 7.50 | 90.8 | 141.9 | 91.3 | 11.11 |
| 27-Aug-12 | 20.44 | 7.82 | 135.5 | 73.7 | 100.9 | 9.09 |
| 01-Mar-13 | 5.86 | 7.43 | 85.7 | 106.9 | 94.6 | 11.90 |

**Table 4:** Deep Water (11.1 – 12.3 m) Averages for pH, conductivity, ORP, Temperature, Percent Oxygen and Oxygen Concentration (2007 – Present)

| Date | Temperature | pH | Conductivity | ORP | % Oxygen | [Oxygen] |
|---|---|---|---|---|---|---|
| Units | °C | pH units | µS/cm | mV | % | mg/L |
| 13-Apr-07 | 7.85 | | | | 0.8 | 0.09 |
| 09-Nov-07 | | | | | 2.7 | 0.32 |
| 24-Apr-08 | 7.18 | 7.25 | 170 | -18.8 | 19.0 | 2.03 |
| 20-Oct-09 | 9.80 | 6.64 | 178 | 87.2 | 6.8 | 0.77 |

**Table 4:** Con't.

| Date | Temperature | pH | Conductivity | ORP | % Oxygen | [Oxygen] |
|---|---|---|---|---|---|---|
| Units | °C | pH units | μS/cm | mV | % | mg/L |
| 20-Apr-09 | 6.82 | 4.99[9] | 129 | -44.7 | 34.0 | 4.12 |
| 13-Nov-09 | 8.46 | 6.66 | 187 | -24.9 | 9.6 | 1.12 |
| 03-May-10 | 8.21 | 7.10 | 126 | 50.4 | 106.4 | 12.47 |
| 02-Dec-10 | 4.69 | 6.43 | 102 | -40.6 | 52.8 | 6.82 |
| 09-May-11 | 7.04 | 7.18 | 89 | 48.5 | 34.7 | 4.21 |
| 14-Nov-11 | 7.52 | 7.05 | 158 | -44.4 | 78.6 | 9.52 |
| 27-Aug-12 | 8.77 | 6.78 | 132.5 | -68.2 | 6.8 | 0.38 |
| 01-Mar-13 | 5.39 | 7.50 | 83.3 | 87.2 | 83.1 | 7.27 |

Laboratory Analytical Data

Water samples were submitted to ALS Laboratories on 01 March 2013 under sealed chain-of-custody. The requested sample parameters to be analyzed for SWMP-01, SWMP-03, SWMP-03D and SWMP-04 included the following:

- pH and Hardness ($CaCO_3$)
- Anions (fluoride, chloride, nitrate and sulphate)
- Nutrients (Ammonia Nitrogen and Total Phosphorus)
- Nitrate and Nitrite
- Total Kjeldahl Nitrogen[10]
- Dissolved Metals
- True Colour
- Total Carbon
- Total Organic Carbon
- Chlorophyll-A

Samples SWMP-06 and WET-01 were submitted for TSS and Turbidity analysis.

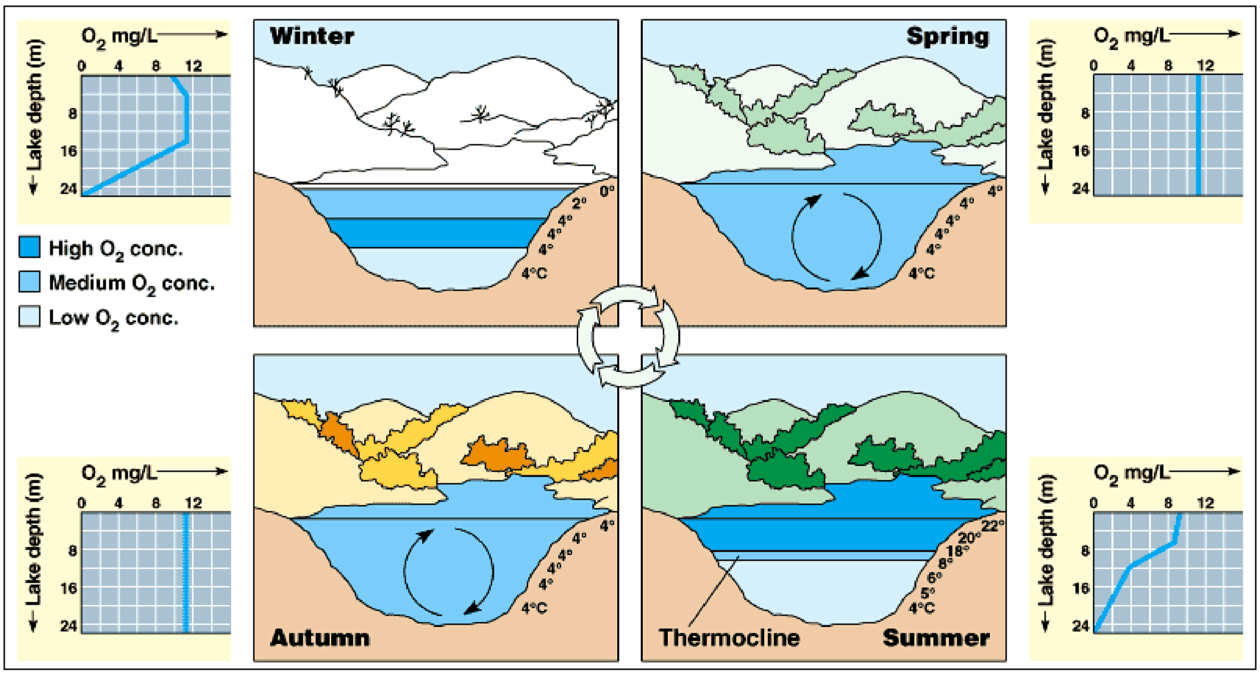
The laboratory results were emailed to AquaTerra on 12 March 2013 and are summarized in **Appendix I**. Historical (i.e., Winter [September] 2006, Spring [April] 2007, Fall [November] 2007, Spring [April] 2008, Fall [October] 2008, Spring [April] 2009, Fall [November] 2009), Spring [May] 2010, Fall [December] 2010, Spring [May] 2011, Fall [November] 2011 and Summer [August] 2012) results have also been included for comparative purposes. The ALS Laboratories analytical report for the Spring 2013 results are included in **Appendix II**.

[9] Low pH attributed to faulty pH probe during this sampling event.
[10] organic nitrogen; ammonia, $NH_3$ and ammonium, $NH_4^+$

Discussion of Lake Processes and Analytical Results

Seasonal lake stratification and de-stratification are a common occurrence and can affect the physiochemical parameters and chemical composition of a lake (**Figure 1**). Stratification, which occurs primarily during the summer in temperate regions, occurs because the temperature of the water in the water column becomes less uniform between the top (epilimnion) and the bottom (hypolimnion), resulting in a temperature gradient. As a result, water at the surface becomes less dense and floats above the denser, cooler water beneath it. During stratification, less mixing occurs between layers, often resulting in an oxygenated epilimnion and little (hypoxic)-to-no (anoxic) oxygen containing hypolimnion. In the fall, stratification breaks down as a result of cooler temperatures and the lake mixes (termed ‘autumn overturn’) as a result of uniform water density, recharging the bottom water with oxygen and bringing nutrients up to the surface. The result permits a greater vertical movement for aquatic inhabitants within the water column without experiencing hypoxia. Winter conditions can also result in stratification, termed ‘winter stagnation’, which becomes more pronounced during sub-zero temperatures resulting in ice formation. Again, in the spring, stratification breaks down resulting in ‘spring overturn’.

**Figure 1:** Typical Lake Annual Stratification and De-Stratification Cycle



*Physicochemical Parameters*

pH and Temperature

In Spring 2013, the surface water field pH (average: 7.43) was slightly basic but generally closer to neutral (pH=7) relative to previous sampling events. pH at the lake bottom (average: 7.50) closely mirrored surface conditions and was relatively neutral compared to the often acidic pH conditions observed historically. The periodic increased acidity, at depth, is the result of lower oxygen levels and the formation of hydrogen sulfide (a weak acid) during decomposition of organic matter.

The Spring 2013 monitoring event marked the second coldest average lake temperature (5.86 $^{o}$C) – the coldest being in December 2010. The average temperature at the bottom of the lake (5.39 $^{o}$C) was fairly consistent with the surface temperature and was also coldest with the exception of December 2010. In some instances, particularly during the winter period, the lake bottom is warmer than the surface as a result of decreased mixing.

Hardness

Water hardness is generally due to the presence of calcium and magnesium in the water. Other metallic ions may also contribute to hardness. Waters with values exceeding 120 mg/L are considered 'hard' whereas values below 60 mg/L are considered 'soft'. Spring 2013 water hardness results averaged 47.3 mg/L. Results are similar to the Spring and Fall 2011 water hardness averages, which were 45.0 mg/L and 48.7 mg/L, respectively. Harder water was recorded in Summer 2012 (54.6 mg/L) and Fall 2009 (60 mg/L).

To date, calcium and magnesium concentrations were highest in Fall 2009 (refer to the *Ion Concentrations and Metals* section for additional details). The Spring 2013 calcium and magnesium concentrations fell within the range of historical results. The higher calcium and magnesium concentrations in Fall 2009 and Summer 2012 are likely attributable to the extended, abnormally dry periods.

Conductivity

Conductivity is the measurement of the ability of water to conduct an electrical current. The greater the content of ions in the water, the more current the water can carry. Ions are dissolved metals and other dissolved materials. Typical conductivity ranges for coastal BC waterbodies are ~100 μS/cm with ranges between 50 – 1500 μS/cm. Enos Lake falls well within this broad spectrum. Spring 2013 surface water conductivity (85.7 μS/cm) is the lowest to date (average: 113.4 μS/cm). As noted previously, the reason for the lower conductivity is anticipated to be the result of a lower ion concentration, which is likely attributable, in part, to the early sample timing and elevated lake levels. Marginal variation in conductivity can also be attributed to rainfall events and the proximity to the ocean (deposition of sodium, chloride, magnesium, and sulphate ions) whereas large-scale changes within the water column are the result of decreased mixing and increased density of the water at the bottom of the lake (stratification).

Oxidation-Reduction Potential

ORP is a non-specific measurement—that is, the measured potential is reflective of a combination of the effects of all the dissolved species in the medium. Reduction-Oxidation (REDOX) reactions (which are measured by ORP) occur within lakes as a result of photosynthesis and respiration often resulting in the production of hydrogen sulfide gas at the bottom of lakes, resulting in low oxygen levels and negative ORP values. In general, the more negative the ORP value (i.e., the higher its negative ORP), the more likely it is to engage in chemical reactions that donate electrons.

Generally, ORP values of >400 mV are deemed to be potentially harmful to aquatic life. The Spring 2010 monitoring event was the first recorded occurrence in which ORP did not transition from a positive (i.e., oxidizing) state at the lake's surface to negative (i.e., reducing) state in the vicinity of the lake bottom. These conditions were repeated again during the 2011 Spring monitoring event and again during this most recently monitoring event. Positive ORP values at the bottom of the lake are anticipated to be the result of oxygen levels being sufficient to meet the oxygen demand for processes occurring on or near the bottom of the lake coupled to the release of oxygen during photosynthesis. Akin to previous monitoring events, ORP values continue to be highest at SWMP-06, which is located closest to the wetland. Heavy rainfall events or increased wetland discharges can flush iron into the lake, affecting ORP through the conversion of iron between soluble and insoluble forms. The periodic wetland turbidity and Enos Lake iron concentrations appear to confirm this assertion.

Oxygen Concentration

Oxygen levels were generally stable across the surface of the lake (11.90 mg/L – 94.6%), being close to full saturation. Generally, surface oxygen levels increased to the north and may be the result of wetland inputs, where biological activity is higher. These results were also observed during the 2011 and 2012 sampling events. Oxygen concentration remained relatively uniform at depths up to ~11.1 – 12.3 m, at which point oxygen levels declined. Even near the bottom of the lake (12.3 m), oxygen ranged from 9.80 – 10.30 mg/L – 76.7 – 81.5%). For comparative purposes, fish are impaired at oxygen concentrations of less than 30% saturation; however, certain species, such as the Three-spined Stickleback (*Gasterosteus aculeatus*) can tolerate stagnant ditches with oxygen concentrations of less than 2 mg/L. Annual fluctuations in climatic conditions (i.e., amount of rainfall and ambient temperature) and storm events both play a significant role in oxygen concentration and resulting productivity of Enos Lake.

Supersaturation (>100% saturation) is typically observed during the mid-spring monitoring events and occurs when increasing temperatures and longer daylight hours result in increases in algae (phytoplankton) and aquatic plant density, which drive the following photosynthetic reaction:

$$CO_2 + H_2O \Rightarrow CH_2O + O_2 \uparrow$$

In highly productive lakes, the reaction is reversed (respiration) at night as oxygen is consumed and photosynthesis is not occurring. As a result, dissolved oxygen may drop to levels which may be hypoxic or anoxic to many aquatic organisms (Macan 1974). Of note, the majority of fish species cannot survive at concentrations below 3-4 mg/L for extended periods.

*Total Suspended Solids and Turbidity*

Total Suspended Solids (TSS) and turbidity remained low in Enos Lake. The turbidity (2.1 NTU or less), and TSS (<3 mg/L) were well below the historical highs recorded in Fall 2011 (22.5 NTU; 5.8 mg/L). The low spring turbidity and TSS results are anticipated to be due to the calm and dry weather conditions at the time of sampling and particularly low turbidity within the Enos Lake wetland (<3 mg/L), which was below the typical values reported during previous monitoring events.

Commonly enforced turbidity thresholds are 25 NTU on dry days and 100 NTU on rainy days (>25 mm rainfall). Similarly, TSS thresholds are 25 mg/L on dry days and 75 mg/L on rainy days (source: DFO Land Development Guidelines [1992] and DFO Turbidity Criteria [2008]).

*Total Carbon and Total Organic Carbon*

Total Carbon (TC) is the sum of both total organic carbon (TOC) and total inorganic carbon (TIC) sources (i.e. TC = TOC + TIC) and is often used as a non-specific indicator of water quality. TC can be modulated by number of factors such as lake productivity, mineral precipitation, or rates of post-burial organic matter decomposition.

TOC is the sum of carbon originating from natural, decaying organic matter as well as synthetic sources, such as fertilizer and pesticides. In fresh water systems, TOC typically varies from 1-30 mg/L. Slight oscillations in TOC values are evident between Spring and Fall, suggestive of an increase in biological activity within the lake in the Spring (and current decrease of decaying organic matter as it is sequestered and utilized by growing organisms).

Spring 2013 TC results were higher than historical results with the exception of Fall 2009 (which also had elevated TC results). In contrast, TOC results were low, and in some cases (e.g., SWMP-01) the lowest concentration recorded to-date (3.90 mg/L; average: 5.98 mg/L). In the Spring of 2010, 2011 and 2013, slightly lower TC and TOC levels were reported at SWMP-01, which is anticipated to be the result of dilution (contingent on input rates from the wetland and stormwater detention facilities). Other reported causative factors for decreases in TOC include increasing average temperature, turbidity, changing rainfall patterns, elevated water levels and recovery from acidification.

The analysis of both TC and TOC allows for the calculation of the TIC fraction (via the equation illustrated above). TIC includes dissolved carbon dioxide, carbonic acid, bicarbonate anion and the carbonate anion, which are also involved in lake pH chemical equilibrium. Moreover, the bicarbonate anion, which generally comprises 60-90% of the total TIC fraction, buffers freshwater systems and provides carbon dioxide for photosynthesis. TIC levels can be compared to pH to identify changes in lake photosynthetic processes and carbon dioxide levels. Since the onset of the collection of TOC data (Fall 2008), average TIC levels have varied between 56 and 67 percent; however, in Spring 2013, TIC was 76.4 – 79.0% of the Total Carbon within the lake, the highest results to-date. As noted above, Total Carbon was higher than historical results with the exception of Fall 2009. The higher Total Carbon coupled to slightly TOC resulted in an overall increase in the TIC fraction.

TOC and TIC values are important indicators of potential changes in both lake chemistry and biological function when monitored over time.

*Ion Concentrations and Metals*

Dissolved fluoride, nitrate and sulphate concentrations were within the range of historical results and did not vary between the surface and lake bottom. Similarly, chloride ($Cl^-$) ion concentrations were well within the average range since the collection of data in 2006 and did not vary significantly between the surface and the lake bottom. Chloride concentration is heavily influenced by precipitation rates. Of note, the typical chloride concentration in natural fresh waters is 8.3 mg/L; however, chloride concentration has to be in excess of 230 mg/L to be considered toxic to fresh water aquatic life (Iowa Department of Natural Resources Draft Ambient Aquatic Life Criteria for Chloride, June 2007)[11].

Sulphate concentrations are generally lower in the Summer and Fall (prior to Autumn overturn) relative to the Spring. Specifically, in the Spring, a higher percentage of hydrogen sulphide ($H_2S$) is converted to sulphate as there is generally more oxygen present within the deeper portions of the lake. In contrast, in the summer and fall, because the lake bottom is more often characterized by a low oxygen concentration, a larger proportion of the sulphate will have been converted to hydrogen sulphide, resulting in a lower sulphate ion concentration.

Dissolved aluminum, calcium, iron, magnesium, and sodium concentrations were well within the ranges of historical results. Manganese concentrations began to show a decline in Spring 2011;

[11] Available online here: http://www.iowadnr.gov/water/standards/files/cissue.pdf

however, between Summer 2012 and Spring 2013 there has been a rapid increase in manganese concentrations across the lake and at depth. Specifically, manganese concentration in Summer 2012 was <0.3 μg/L increasing to between 17.4 – 18.8 μg/L in Spring 2013 – a nearly 60-fold increase.

The Fall 2008 (fall season) manganese levels were 2-3 times higher than in previous samples and may have been attributed to a cull of Signal Crayfish (summer 2008), which were disposed of in the deepest part of the lake. In Spring and Fall 2009, manganese concentrations continued to increase, decreasing again in Spring 2010 and Spring 2011. Specifically, manganese levels were approximately 10 μg/L less in Spring 2011 relative to Spring 2010. The Fall 2011 manganese levels (3.79 to 4.36 μg/L) were the lowest since Spring 2008 and in the range of pre-cull levels (2 – 6 μg/L), which was suggested as being potentially the result of a recovering Signal Crayfish population. Summer 2012 results were even lower (<0.3 μg/L), being the lowest concentration recorded since the onset of monitoring in 2006. It is well documented in the literature that crayfish and lobster species can readily sequester and accumulate manganese in their soft tissues, which is released during decomposition. Other potential explanations for lower manganese concentrations in Summer 2012 is related to the late sample timing, which coincided with significantly less precipitation and wind inputs, thereby reducing manganese concentrations at the surface, and the associated thermal stratification, resulting in higher manganese concentrations at the lake bottom, where it actively participates in redox reactions where little-to-no oxygen is present. Manganese concentration has been shown to be related to thermal stratification and redox environment of lakes (Delfino and Lee, 1971). Manganese inputs through stormwater and watercourse inputs as well as atmospheric deposition and rainfall are also potential contributing factors.

*Nutrients*

In general, reported nutrients were within the typical ranges since the onset of data collection (varying times between 2007 and 2009). Specifically, ammonia nitrogen continued to be low, and nitrate/nitrite, TKN, Total Organic Nitrogen and Total Nitrogen were within the range of historical results. Results at the lake bottom were similar to surface water concentrations. Freshwater systems generally have ammonia values of less than 0.1 mg/L, which is reflective of the results to-date. Ammonia concentrations should not exceed 1-2 mg/L for extended periods to be protective of aquatic life.

Reported Spring 2013 total phosphorus levels (11.7 – 12.8 μg/L) were within the range of historical results to-date. The total phosphorous concentration at the lake bottom (12.6 μg/L) was akin to surface concentrations. In many cases, phosphorus is often the limiting nutrient in freshwater systems, given that it is largely unavailable atmospherically and is typically converted into forms prior to being utilized for biological productivity (e.g. algal growth). Low phosphorous concentrations can affect Chlorophyll-A production (refer to the 'Chlorophyll-A' section below, for details). Higher phosphorus concentrations can result in rapid increases in biological production within a given lake, resulting in murky water and an increased density of aquatic plants. In lakes where biological productivity is extremely high, water quality can be impaired to the point where recreational activities may be limited, fish populations may be inhibited and drinking/irrigation water use may be affected.

*True Colour*

True Colour is measured in Colour Units (CU) and is the result of humic substances, soil and aquatic micro-organisms [i.e., bacterial, aquatic plant life, and phytoplankton] and resulting by-products suspended in the water column. True Colour is directly correlated to Chlorophyll-A (discussed in detail below).

A True Colour value of 15 CU can be detected in a glass of water by most consumers, and a True Colour of 5 CU will be apparent in large volumes of water, such as in a bathtub. The current B.C. Ambient Water Quality Guidelines for colour for use by aquatic life states that the 30-day average True Colour of filtered water samples shall not exceed background levels by more than 5 CU in clearwater systems or 20% in coloured systems.

Spring 2013 analytical results for True Colour were relatively homogeneous across the lake (12.4 to 13.1 CU). Lake bottom results (12.7 CU) did not vary markedly relative to surface water results. True Colour results were in line with other historical earlier spring monitoring events (2008 and 2009). Until Winter 2010, True Colour results had been higher in the Spring and Summer and lower in the Fall/Winter, which is anticipated to be due, in part, to a downturn in primary production. Specifically, True Colour results in Winter 2010 and Fall 2011 were higher in some instances than the True Colour values from earlier in the year. These results are anticipated to be due, in part, to the higher than normal Chlorophyll-A results during that same time period; however, as noted previously, suspended material in the water column and the release of humic substances can also play a modulating role.

*Chlorophyll-A*

Spring 2013 marks the eighth time that Chlorophyll-A has been sampled as a component of the Fairwinds Enos Lake water quality monitoring program. Like many water quality measurements taken over time, Chlorophyll-A concentrations can be used to identify trends and establish why these changes may be occurring. Chlorophyll-A is a specific pigment that occurs in plant cells and is used to measure the biomass of phytoplankton in water samples. Under suitable conditions (i.e., nutrient loading as a result of run-off, organic waste / sewage discharge, accumulation of detritus, etc.), quantities of phytoplankton may increase significantly (eutrophication), using up much of the available oxygen in the water column such that it can create hypoxic or anoxic conditions for other aquatic inhabitants.

Under typical conditions, a Chlorophyll-A value of 40 µg/L or greater is indicative of an algal bloom (Stanley et al., 2003). Research has identified a strong correlation between the concentration of Total Phosphorus (TP) and Chlorophyll-A (Sakamoto 1966; Dillion and Rigler 1974; Jones and Bachmann 1976; Carlson 1977). A more recent study (Stanley et al., 2003) identified a trend between Chlorophyll-A, nitrogen, and phosphorus suggesting that phosphorus is the limiting nutrient below TP levels of 100 µg/L, and that nitrogen is the limiting nutrient above 100 µg/L.

Spring 2013 Chlorophyll-A levels ranged from 4.25 µg/L to 10.2 µg/L, being lowest at SWMP-03. Of interest, the Chlorophyll-A level at the lake bottom at SWMP-03 (9.29 µg/L) was higher than at the surface; however these results should be interpreted with caution as the other two surface Chlorophyll-A levels were 10.1 µg/L (SWMP-01) and 10.2 µg/L (SWMP-04). Unlike some previous years, the Chlorophyll-A at SWMP-01 was not higher relative to other locations. Qualitative and quantitative observations at the nearby wetland during the Spring 2013 monitoring event were indicative of lower than normal turbidity and TSS levels, which may be the result of reduced wetland inputs or improved discharge water quality (as a result of improved passive stormwater treatment).

In Spring 2009, Chlorophyll-A levels in Enos Lake were high, ranging from 18.1 to 19.8 µg/L (average: 19.0 µg/L), and reflecting the low water visibility as well as the low phosphorus and nitrogen in the lake at the time, which are quickly sequestered by bacteria, aquatic plants and phytoplankton. The high Spring Chlorophyll-A levels may be partially attributable to nutrient upwelling during spring overturn and may also be higher than usual (which can be established through additional monitoring events) as a result of the Signal Crayfish cull (summer 2008), which were disposed of in the deepest part of the lake, thereby releasing additional nutrients into the water over a relatively short period of time. Seasonal Chlorophyll-A spikes have also been observed in other lake studies (Jones and Federico 1984), with highest concentrations observed in the spring-summer, and lowest concentrations in the winter. The Jones and Federico study noted a 1000-fold increase in Chlorophyll-A production in the spring-summer, which is reportedly a common occurrence for temperate lakes.

In contrast to the elevated Spring 2009 results, Chlorophyll-A results in Fall 2009 were <0.10 – 0.17 µg/L (average: 0.15 µg/L), or 127-fold (75%) less. The Winter 2010 results (1.44 – 7.14 µg/L) were significantly higher than the previous Fall/Winter monitoring event and may be the result of higher phosphate levels (and concurrent increase in biological activity). In Fall 2011, chlorophyll-A levels (7.75 to 10.2 µg/L) were significantly higher than previous Fall/Winter sampling events. Summer 2012 results (0.47 – 1.83 µg/L) were lower than expected and is likely attributable to low nutrient levels during this period. Prior to this, analytical results have suggested that the lake had become largely inactive by mid-late November. This elevated Chlorophyll-A levels during the Fall 2011 monitoring event are anticipated to be linked to elevated nitrogen and iron levels (discussed in previous sections). An analysis of stormwater run-off into the wetland and sampling at major watercourse discharges may serve to better evaluate sources and inputs.

Annual variations in climatic conditions and inputs will influence Chlorophyll-A concentrations; however, additional years of data will serve to further evaluate trends and contributing factors, if any.

The Trophic State Index (TSI) was calculated for Chlorophyll-A using the following formula:

$$\text{TSI (Chlorophyll A)} = 9.81 \ln(\text{Chlorophyll A}) + 30.6$$

TSI is a standardized method for determining lake nutrient conditions (Carlson 1977). The rating scheme is provided in **Table 4**.

**Table 4:** TSI Trophic Ratings

| TSI | Trophic state | Attributes | Aquatic life |
|---|---|---|---|
| < 30 | Oligotrophic | Clear water<br>Low production<br>Oxygenated hypolimnion | Trout possible in deep lakes |
| 30 – 50 | Mesotrophic | Moderately clear water<br>Possible anoxia in summer | Warm water fishery |
| 50 – 70 | Eutrophic | Low transparency<br>Anoxic hypolimnion in summer | Warm water fishery |
| > 70 | Hypereutrophic | Dense algae and macrophytes<br>Noticeable odor | Fish kills possible |

Table adapted from the US Environmental Protection Agency (USEPA), 1999, p.4-2.

In the United States, the West Virginia Department of Environmental Protection (DEP) defines a lake as “impaired” when TSI $\geq$ 65. Based on the highest Chlorophyll-A concentration measured in Enos lake (19.8 µg/L) to date (Spring 2009), the TSI value was 59.9, which is close to the DEP impairment threshold. Impairment denotes a lake condition in which natural biological function may be compromised given that water quality standards are not met. Maximum TSI values for Summer 2012 (31.8), Fall 2011 (52.5) and Fall/Winter 2010 (32.6) varied significantly. Until the most recent two sampling events, it was presumed that the lake appears to shift from a mesotrophic-eutrophic state in the spring-summer, to an oligotrophic-mesotrophic state in the fall-winter; however, it is anticipated that external lake inputs have an over-riding influence on the lake’s trophic state.

Of note, the mean Chlorophyll-A value (measured each month over a 12-month cycle) is most typically used in evaluating a lake's overall trophic state. The low phosphorous levels suggest a 'oligotrophic-to-mesotrophic' designation, and is reflective of the current classification of Enos Lake's trophic state; however, total phosphorus levels are to be monitored closely to evaluate changes over time.

We trust this provides the information you currently require. Should you have any questions, please feel free to contact the undersigned.

Respectfully submitted,

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# APPENDIX I

## Enos Lake and Enos Lake Wetland
## **Early Spring 2013 and Historical Analytical Results**

**Laboratory Analytical Results - Monitoring Location SWMP-01**

| Sample ID | | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 | SWMP-01 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date (Y/M/D) | | 2006 09-15 | 2007 04-13 | 2007 11-13 | 2008 04-24 | 2008 10-20 | 2009 04-20 | 2009 11-13 | 2010-05-03 | 2010-12-20 | 2011-05-09 | 2011-11-14 | 2012-08-27 | 2013-03-01 |
| **Parameter** | **Units** | | | | | | | | | | | | | |
| pH, Laboratory | pH | 7.73 | 7.51 | 7.7 | 7.89 | 7.80 | 7.97 | 8.04 | 7.9 | 7.78 | 7.88 | 7.92 | 7.80 | 8.00 |
| Hardness $CaCO_3$ | mg/L | 55 | 44 | 49 | 47 | 50 | 56 | 61 | 48.6 | 48.8 | 45.3 | 48.6 | 54.5 | 47.9 |
| Total Carbon | mg/L | - | - | 15 | 17 | 17 | 17 | 19 | 15.2 | 15.3 | 14.4 | 14.6 | 14.6 | 18.6 |
| Total Organic Carbon | mg/L | - | - | - | - | 7.6 | 5.7 | 6.2 | 6.3 | 6.00 | 5.84 | 6.28 | 5.99 | 3.90 |
| True Colour | CU | - | - | 7 | 10 | 8 | 13 | <5 | 15 | 14.8 | 10.5 | 11.9 | 8.7 | 12.4 |
| Total Suspended Solids | mg/L | 2 | <1 | 2 | 1 | 2 | <1 | 1 | <4 | <3 | <3 | <3 | <3 | - |
| Turbidity | NTU | - | - | - | 1.2 | 1.3 | 1.5 | 0.81 | 2.1 | 2.06 | 2.19 | 1.75 | 1.0 | 2.01 |
| Dissolved Fluoride | ug/L | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | <50 | <20 | 23 | 20 | 28 | <30 | 26 |
| Dissolved Chloride | mg/L | 11.3 | 10.2 | 11.1 | 12.3 | 13.3 | 15.9 | 17.5 | 12 | 12.6 | 9.69 | 10.6 | 12.1 | 11.6 |
| Dissolved Nitrate | mg/L | < 0.05 | < 0.05 | < 0.05 | < 0.01 | < 0.01 | < 0.01 | 0.02 | <0.02 | 0.111 | <0.005 | <0.005 | <0.005 | 0.058 |
| Dissolved Sulphate | mg/L | 4.14 | 5.01 | 4.22 | 4.78 | 4.56 | 5.76 | 3.78 | 5.2 | 5.21 | 5.16 | 4.78 | 4.51 | 5.49 |
| Ammonia Nitrogen | mg/L | 0.09 | < 0.01 | 0.06 | 0.03 | 0.10 | 0.02 | 0.07 | 0.05 | <0.005 | <0.005 | 0.0341 | 0.008 | <0.005 |
| Nitrate and Nitrite | mg/L | - | - | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 0.02 | <0.02 | 0.111 | <0.006 | <0.006 | <0.006 | 0.0580 |
| Total Kjeldahl Nitrogen | mg/L | - | - | 0.2 | 0.3 | 0.4 | 0.7 | 0.4 | 0.30 | 0.524 | 0.257 | 0.495 | 0.371 | 0.457 |
| Total Organic Nitrogen | mg/L | - | - | - | - | - | - | 0.3 | 0.30 | 0.524 | 0.257 | 0.495 | 0.371 | 0.457 |
| Total Nitrogen | mg/L | - | - | 0.2 | 0.3 | 0.4 | 0.7 | 0.4 | 0.3 | 0.524 | 0.370 | 0.495 | 0.430 | 0.515 |
| Total Phosphorus | mg/L | 0.02 | < 0.02 | < 0.02 | < 0.02 | 0.02 | < 0.02 | < 0.02 | 0.009 | 0.0133 | 0.0116 | 0.0117 | 0.0082 | 0.0127 |
| Chlorophyll-A | | - | - | - | - | - | 19.8 | 0.17 | 7.0 | 5.42 | 2.05 | 10.0 | 0.468 | 10.8 |

## Laboratory Analytical Results (Metals) - Monitoring Location SWMP-01

| Sample ID | | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** | **SWMP-01** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date (Y/M/D) | | 2006 09-15 | 2007 04-13 | 2007 11-13 | 2008 04-24 | 2008 10-20 | 2009 04-20 | 2009 11-13 | 2010-05-03 | 2010-12-20 | 2011-05-09 | 2011-11-14 | 2012-08-27 | 2013-03-01 |
| **Parameter** | **Units** | | | | | | | | | | | | | |
| Dissolved Aluminum | ug/L | 27 | 10 | 6 | 11 | 12 | 12 | 16 | 16 | 14 | 19.9 | <5 | 22.1 | 12 |
| Dissolved Antimony | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Arsenic | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | 0.1 | 0.1 | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Barium | ug/L | 17 | 13 | 18 | 15 | 16 | 19 | 19 | 17 | <20 | <20 | <20 | <20 | <20 |
| Dissolved Beryllium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <0.1 | <5 | 1 | <1 | <1 | <1 |
| Dissolved Bismuth | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <1 | n/a | n/a | n/a | n/a | n/a |
| Dissolved Boron | ug/L | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | 140 | <50 | <100 | <100 | <100 | <100 | <100 |
| Dissolved Cadmium | ug/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.05 | <0.01 | <0.05 | 0.177 | <0.017 | <0.017 | <0.01 |
| Dissolved Calcium | ug/L | 19000 | 15300 | 16800 | 16100 | 17400 | 19400 | 20400 | 16500 | 16400 | 15400 | 16500 | 18600 | 16300 |
| Dissolved Cesium | ug/L | - | - | - | - | - | - | < 0.5 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Chromium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | <1 | <0.5 | <1 | <1 | <1 | <1 |
| Dissolved Cobalt | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <0.5 | <0.5 | <0.3 | <0.3 | <0.3 | <0.3 |
| Dissolved Copper | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | 0.7 | <1 | <1 | <1 | <1 | <1 |
| Dissolved Iron | ug/L | 70 | < 50 | 60 | < 50 | < 50 | < 50 | 50 | 53 | 72 | 33 | 101 | 33 | 41 |
| Dissolved Lead | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.25 | <0.2 | <1 | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Lithium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | 4 | <5 | <5 | <5 | <5 | <5 | <5 |
| Dissolved Magnesium | ug/L | 1920 | 1390 | 1770 | 1560 | 1620 | 1930 | 2330 | 1810 | 1900 | 1650 | 1770 | 1960 | 1760 |
| Dissolved Manganese | ug/L | < 1 | 15 | 4 | 6 | 18 | 22 | 48 | 25 | 22 | 9.48 | 3.79 | <0.3 | 17.4 |
| Dissolved Mercury | ug/L | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | <0.02 | <0.2 | <0.01 | <0.01 | <0.01 | <0.01 |
| Dissolved Molybdenum | ug/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | <1 | <1 | <1 | <1 | <1 | <1 |
| Dissolved Nickel | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | <1 | <5 | <1 | <1 | <1 | <1 |
| Dissolved Phosphorus | ug/L | < 150 | < 150 | < 150 | < 150 | < 150 | < 150 | < 75 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Potassium | ug/L | 300 | 300 | 400 | 300 | 300 | 400 | 780 | 310 | n/a | <2000 | <2000 | <2000 | <2000 |
| Dissolved Rubidium | ug/L | - | - | - | - | - | - | 0.5 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Selenium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | n/a | <1 | <1 | <1 | <1 | <1 |
| Dissolved Silicon | ug/L | 1100 | 1900 | 1700 | 2000 | 1300 | 2100 | 1800 | 2830 | n/a | n/a | n/a | n/a | n/a |
| Dissolved Silver | ug/L | < 0.25 | < 0.25 | | < 0.25 | < 0.25 | < 0.25 | < 0.2 | <0.02 | <0.05 | <0.02 | <0.02 | <0.02 | <0.02 |
| Dissolved Sodium | ug/L | 7980 | 6620 | 7510 | 6700 | 6860 | 8540 | 10600 | 7520 | 7900 | 7200 | 7800 | 8200 | 8000 |
| Dissolved Strontium | ug/L | 50 | 41 | 49 | 51 | 49 | 54 | 56 | 47 | n/a | n/a | n/a | n/a | n/a |
| Dissolved Tellurium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Thallium | ug/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | <0.05 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Dissolved Thorium | ug/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.25 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Tin | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <5 | n/a | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Titanium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | <5 | <50 | <10 | <10 | <10 | <10 |
| Dissolved Uranium | ug/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.25 | <0.1 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Dissolved Vanadium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <5 | <30 | <1 | <1 | <1 | <1 |
| Dissolved Zinc | ug/L | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Dissolved Zirconium | ug/L | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 0.5 | <0.5 | n/a | n/a | n/a | n/a | n/a |

**Laboratory Analytical Results - Monitoring Location SWMP-03**

| Sample ID | | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date (Y/M/D) | | 2006 09-15 | 2007 04-13 | 2007 11-13 | 2008 04-24 | 2008 10-20 | 2009 04-20 | 2009-11-13 | 2010-05-03 | 2010-12-20 | 2011-05-09 | 2011-11-14 | 2012-08-27 | 2013-03-01 |
| **Parameter** | **Units** | | | | | | | | | | | | | |
| pH, Laboratory | pH | 7.84 | 7.66 | 7.62 | 7.9 | 7.86 | 7.99 | 7.98 | 7.8 | 7.87 | 7.90 | 7.92 | 7.88 | 7.87 |
| Hardness $CaCO_3$ | mg/L | 53 | 43 | 48 | 49 | 50 | 55 | 60 | 49.6 | 49.2 | 45.1 | 48.6 | 54.8 | 47.3 |
| Total Carbon | mg/L | - | - | 15 | 16 | 17 | 17 | 19 | 13.4 | 16.0 | 14.2 | 15.6 | 14.2 | 18.3 |
| Total Organic Carbon | mg/L | - | - | - | - | 6.8 | 5.5 | 6.2 | 4.5 | 6.46 | 5.66 | 6.20 | 5.98 | 4.22 |
| True Colour | CU | - | - | < 5 | 10 | 8 | 13 | 5 | 20 | 15.1 | 10.5 | 10.2 | 7.7 | 12.5 |
| Total Suspended Solids | mg/L | 1 | <1 | 3 | < 1 | 1 | 1 | 1 | <4 | <3 | <3 | <3 | <3 | - |
| Turbidity | NTU | - | - | - | 1.2 | 1.4 | 1.5 | 0.84 | 2.1 | 2.32 | 2.09 | 1.78 | 0.79 | 2.09 |
| Dissolved Fluoride | ug/L | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | <20 | <20 | <20 | 26 | 31 | 23 |
| Dissolved Chloride | mg/L | 11.1 | 10 | 11.1 | 12.2 | 13.4 | 15.8 | 17.4 | 12 | 12.9 | 9.62 | 10.5 | 12.1 | 11.5 |
| Dissolved Nitrate | mg/L | < 0.05 | 0.05 | < 0.05 | < 0.01 | < 0.01 | < 0.01 | 0.01 | <0.02 | 0.10 | <0.005 | <0.005 | <0.005 | 0.0622 |
| Dissolved Sulphate | mg/L | 4.34 | 5.03 | 4.24 | 4.67 | 4.73 | 5.71 | 3.76 | 6.7 | 4.90 | 5.13 | 4.78 | 4.84 | 5.46 |
| Ammonia Nitrogen | mg/L | < 0.01 | 0.01 | 0.06 | < 0.01 | < 0.01 | < 0.01 | 0.08 | 0.054 | <0.005 | <0.005 | 0.0439 | <0.005 | <0.005 |
| Nitrate and Nitrite | mg/L | - | - | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 0.01 | <0.02 | 0.100 | <0.006 | <0.006 | <0.006 | 0.0633 |
| Total Kjeldahl Nitrogen | mg/L | - | - | 0.2 | 0.8 | 0.5 | 0.5 | 0.4 | 0.25 | 0.524 | 0.238 | 0.526 | 0.315 | 0.453 |
| Total Organic Nitrogen | mg/L | - | - | - | - | - | - | 0.3 | 0.25 | 0.524 | 0.238 | 0.526 | 0.315 | 0.453 |
| Total Nitrogen | mg/L | - | - | 0.2 | 0.8 | 0.5 | 0.5 | 0.4 | 0.25 | 0.524 | 0.320 | 0.526 | 0.390 | 0.516 |
| Total Phosphorus | mg/L | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | 0.008 | 0.0121 | 0.0106 | 0.0122 | 0.0066 | 0.0117 |
| Chlorophyll-A | | - | - | - | - | - | 18.1 | 0.17 | 5.5 | 7.14 | 5.36 | 10.2 | 1.08 | 4.25 |

**Laboratory Analytical Results (Metals) - Monitoring Location SWMP-03**

| Sample ID | | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 | SWMP-03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date (Y/M/D) | | 2006 09-15 | 2007 04-13 | 2007 11-13 | 2008 04-24 | 2008 10-20 | 2009 04-20 | 2009 11-13 | 2010-05-03 | 2010-12-20 | 2011-05-09 | 2011-11-14 | 2012-08-27 | 2013-03-01 |
| **Parameter** | **Units** | | | | | | | | | | | | | |
| Dissolved Aluminum | ug/L | 24 | 7 | 7 | 11 | 8 | 14 | 15 | 16 | 13 | 19.2 | <5 | 20.7 | 11.8 |
| Dissolved Antimony | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Arsenic | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | 0.2 | <1 | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Barium | ug/L | 18 | 14 | 18 | 17 | 15 | 18 | 19 | 17 | <20 | <20 | <20 | <20 | <20 |
| Dissolved Beryllium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <0.1 | <5 | <1 | <1 | <1 | <1 |
| Dissolved Bismuth | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <1 | n/a | n/a | n/a | n/a | n/a |
| Dissolved Boron | ug/L | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | 60 | <50 | <100 | <100 | <100 | <100 | <100 |
| Dissolved Cadmium | ug/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.05 | <0.01 | <0.05 | <0.017 | <0.017 | <0.017 | <0.01 |
| Dissolved Calcium | ug/L | 18100 | 15100 | 17900 | 17000 | 17300 | 19100 | 20100 | 16900 | 16600 | 15400 | 16600 | 18700 | 16200 |
| Dissolved Cesium | ug/L | - | - | - | - | - | - | < 0.5 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Chromium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <1 | <0.5 | <1 | <1 | <1 | <1 |
| Dissolved Cobalt | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <0.5 | <0.5 | <0.3 | <0.3 | <0.3 | <0.3 |
| Dissolved Copper | ug/L | < 1 | < 1 | 2 | < 1 | < 1 | 1 | < 0.5 | 0.8 | <1 | <1 | <1 | <1 | <1 |
| Dissolved Iron | ug/L | 70 | < 50 | 70 | < 50 | < 50 | < 50 | <50 | 47 | 66 | <30 | 107 | <30 | 39 |
| Dissolved Lead | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.25 | <0.2 | <1 | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Lithium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | 3.8 | <5 | <5 | <5 | <5 | <5 | <5 |
| Dissolved Magnesium | ug/L | 1840 | 1340 | 1890 | 1650 | 1730 | 1870 | 2240 | 1790 | 1880 | 1640 | 1750 | 1970 | 1700 |
| Dissolved Manganese | ug/L | < 1 | 11 | 2 | 4 | 30 | 20 | 51 | 22 | 23 | 12.3 | 4.26 | <0.3 | 18.8 |
| Dissolved Mercury | ug/L | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | <0.02 | <0.2 | <0.01 | <0.01 | <0.01 | <0.01 |
| Dissolved Molybdenum | ug/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | <1 | <1 | <1 | <1 | <1 | <1 |
| Dissolved Nickel | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | <1 | <5 | <1 | <1 | <1 | <1 |
| Dissolved Phosphorus | ug/L | < 150 | < 150 | < 150 | < 150 | < 150 | < 150 | < 75 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Potassium | ug/L | 300 | 300 | 300 | 300 | 300 | 400 | 390 | 320 | n/a | <2000 | <2000 | <2000 | <2000 |
| Dissolved Selenium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | <0.1 | <1 | <1 | <1 | <1 | <1 |
| Dissolved Silicon | ug/L | 900 | 1900 | 1700 | 2300 | 1400 | 2200 | 1700 | 2900 | n/a | n/a | n/a | n/a | n/a |
| Dissolved Silver | ug/L | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.2 | <0.02 | <0.05 | <0.02 | <0.02 | <0.02 | <0.02 |
| Dissolved Sodium | ug/L | 7400 | 6450 | 7530 | 7280 | 7120 | 8340 | 10100 | 7590 | 8000 | 7200 | 7700 | 8300 | 7900 |
| Dissolved Strontium | ug/L | 48 | 39 | 48 | 52 | 49 | 53 | 56 | 47 | n/a | n/a | n/a | n/a | n/a |
| Dissolved Tellurium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Thallium | ug/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 1 | < 1 | < 0.1 | n/a | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Dissolved Thorium | ug/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.25 | <5 | n/a | n/a | n/a | n/a | n/a |
| Dissolved Tin | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <5 | n/a | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Titanium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | <5 | <50 | <10 | <10 | <10 | <10 |
| Dissolved Uranium | ug/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.25 | <0.1 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Dissolved Vanadium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <5 | <30 | <1 | <1 | <1 | <1 |
| Dissolved Zinc | ug/L | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Dissolved Zirconium | ug/L | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 0.5 | <0.5 | n/a | n/a | n/a | n/a | n/a |

**Laboratory Analytical Results - Monitoring Location SWMP-DEEP (lake bottom sample at SWMP-03) Compared to SWMP-03**

| Sample ID | | **SWMP-03** | **SWMP-DEEP** |
|---|---|---|---|
| Date (Y/M/D) | | 2013-03-01 | 2013-03-01 |
| **Parameter** | **Units** | | |
| pH, Laboratory | pH | 7.87 | 7.84 |
| Hardness $CaCO_3$ | mg/L | 47.3 | 46.8 |
| Total Carbon | mg/L | 18.3 | 18.3 |
| Total Organic Carbon | mg/L | 4.22 | 4.78 |
| True Colour | CU | 12.5 | 12.7 |
| Total Suspended Solids | mg/L | - | - |
| Turbidity | NTU | 2.09 | 2.10 |
| Dissolved Fluoride | ug/L | 23 | 22 |
| Dissolved Chloride | mg/L | 11.5 | 11.6 |
| Dissolved Nitrate | mg/L | 0.0622 | 0.0579 |
| Dissolved Sulphate | mg/L | 5.46 | 5.46 |
| Ammonia Nitrogen | mg/L | <0.005 | <0.005 |
| Nitrate and Nitrite | mg/L | 0.0633 | 0.0579 |
| Total Kjeldahl Nitrogen | mg/L | 0.453 | 0.481 |
| Total Organic Nitrogen | mg/L | 0.453 | 0.481 |
| Total Nitrogen | mg/L | 0.516 | 0.539 |
| Total Phosphorus | mg/L | 0.0117 | 0.0126 |
| Chlorophyll-A | | 4.25 | 9.23 |

**Laboratory Analytical Results - Monitoring Location SWMP-DEEP (lake bottom sample at SWMP-03) Compared to SWMP-03**

| Sample ID | | SWMP-03 | SWMP-03 |
|---|---|---|---|
| Date (Y/M/D) | | 2013-03-01 | 2013-03-01 |
| **Parameter** | **Units** | | |
| Dissolved Aluminum | ug/L | 11.8 | 11.9 |
| Dissolved Antimony | ug/L | <0.5 | <0.5 |
| Dissolved Arsenic | ug/L | <0.5 | <0.5 |
| Dissolved Barium | ug/L | <20 | <20 |
| Dissolved Beryllium | ug/L | <1 | <1 |
| Dissolved Bismuth | ug/L | n/a | n/a |
| Dissolved Boron | ug/L | <100 | <100 |
| Dissolved Cadmium | ug/L | <0.01 | <0.01 |
| Dissolved Calcium | ug/L | 16200 | 16000 |
| Dissolved Cesium | ug/L | n/a | n/a |
| Dissolved Chromium | ug/L | <1 | <1 |
| Dissolved Cobalt | ug/L | <0.3 | <0.3 |
| Dissolved Copper | ug/L | <1 | 1.5 |
| Dissolved Iron | ug/L | 39 | 38 |
| Dissolved Lead | ug/L | <0.5 | <0.5 |
| Dissolved Lithium | ug/L | <5 | <5 |
| Dissolved Magnesium | ug/L | 1700 | 1690 |
| Dissolved Manganese | ug/L | 18.8 | 19.0 |
| Dissolved Mercury | ug/L | <0.01 | <0.01 |
| Dissolved Molybdenum | ug/L | <1 | <1 |
| Dissolved Nickel | ug/L | <1 | <1 |
| Dissolved Phosphorus | ug/L | n/a | n/a |
| Dissolved Potassium | ug/L | <2000 | <2000 |
| Dissolved Selenium | ug/L | <1 | <1 |
| Dissolved Silicon | ug/L | n/a | n/a |
| Dissolved Silver | ug/L | <0.02 | <0.02 |
| Dissolved Sodium | ug/L | 7900 | 8100 |
| Dissolved Strontium | ug/L | n/a | n/a |
| Dissolved Tellurium | ug/L | n/a | n/a |
| Dissolved Thallium | ug/L | <0.2 | <0.2 |
| Dissolved Thorium | ug/L | n/a | n/a |
| Dissolved Tin | ug/L | <0.5 | <0.5 |
| Dissolved Titanium | ug/L | <10 | <10 |
| Dissolved Uranium | ug/L | <0.2 | <0.2 |
| Dissolved Vanadium | ug/L | <1 | <1 |
| Dissolved Zinc | ug/L | <5 | <5 |
| Dissolved Zirconium | ug/L | n/a | n/a |

## Laboratory Analytical Results - Monitoring Location SWMP-04

| Sample ID | | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date (Y/M/D) | | 2006 09-15 | 2007 04-13 | 2007 11-13 | 2008 04-24 | 2008 10-20 | 2009 04-20 | 2009-11-13 | 2010-05-03 | 2010-12-20 | 2011-05-09 | 2011-11-14 | 2012-08-27 | 2013-03-01 |
| **Parameter** | **Units** | | | | | | | | | | | | | |
| pH, Laboratory | pH | 7.88 | 7.65 | 7.57 | 7.9 | 7.9 | 7.99 | 7.98 | 7.9 | 7.88 | 7.89 | 7.87 | 7.86 | 7.84 |
| Hardness $CaCO_3$ | mg/L | 52 | 43 | 47 | 46 | 49 | 57 | 59 | 49.6 | 48.8 | 44.7 | 49.0 | 54.6 | 47.0 |
| Total Carbon | mg/L | - | - | 15 | 16 | 16 | 16 | 19 | 13.1 | 15.9 | 14.5 | 14.2 | 14.2 | 18.2 |
| Total Organic Carbon | mg/L | - | - | - | - | 7.4 | 5.8 | 6.2 | 4.2 | 6.66 | 5.74 | 6.19 | 6.03 | 4.29 |
| True Colour | CU | - | - | < 5 | 10 | 8 | 13 | 7 | 20 | 15.1 | 9.7 | 11.9 | 7.7 | 13.1 |
| Total Suspended Solids | mg/L | 1 | <1 | 2 | 1 | 1 | <1 | 1 | <4 | <3 | <3 | 3.1 | <3 | - |
| Turbidity | NTU | - | - | - | - | 1.3 | 1.5 | 1.2 | 2.2 | 2.38 | 2.13 | 1.73 | 0.76 | 2.09 |
| Dissolved Fluoride | ug/L | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | <20 | 24 | <20 | 27 | 30 | 27 |
| Dissolved Chloride | mg/L | 11.1 | 9.96 | 11.1 | 12.2 | 13.4 | 15.8 | 17.3 | 12 | 12.7 | 9.65 | 10.5 | 12.1 | 11.5 |
| Dissolved Nitrate | mg/L | < 0.05 | 0.06 | < 0.05 | < 0.01 | < 0.01 | < 0.01 | < 0.03 | <0.02 | 0.0955 | <0.005 | <0.005 | <0.005 | 0.0637 |
| Dissolved Sulphate | mg/L | 4.36 | 5.06 | 4.22 | 4.64 | 4.69 | 5.75 | 3.64 | 6.5 | 4.84 | 5.14 | 4.78 | 4.81 | 5.44 |
| Ammonia Nitrogen | mg/L | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 0.07 | <0.005 | <0.005 | <0.005 | 0.0406 | <0.005 | <0.005 |
| Nitrate and Nitrite | mg/L | - | - | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.03 | <0.02 | 0.0955 | <0.006 | <0.006 | <0.006 | 0.0637 |
| Total Kjeldahl Nitrogen | mg/L | - | - | 0.2 | 0.4 | 0.4 | 0.6 | 0.5 | 0.20 | 0.662 | 0.150 | 0.503 | 0.323 | 0.486 |
| Total Organic Nitrogen | mg/L | - | - | - | - | - | - | 0.4 | 0.20 | 0.662 | 0.150 | 0.503 | 0.323 | 0.486 |
| Total Nitrogen | mg/L | - | - | 0.2 | 0.4 | 0.4 | 0.6 | 0.5 | 0.20 | 0.390 | 0.310 | 0.503 | 0.400 | 0.550 |
| Total Phosphorus | mg/L | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | 0.008 | 0.0122 | 0.0108 | 0.0102 | 0.0065 | 0.0128 |
| Chlorophyll-A | | - | - | - | - | - | 18.5 | < 0.10 | 8.5 | 1.44 | 4.21 | 7.75 | 1.83 | 10.2 |

## Laboratory Analytical Results (Metals) - Monitoring Location SWMP-04

| Sample ID | | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 | SWMP-04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date (Y/M/D) | | 2006 09-15 | 2007 04-13 | 2007 11-13 | 2008 04-24 | 2008 10-20 | 2009 04-20 | 2009 11-13 | 2010-05-03 | 2010-12-20 | 2011-05-09 | 2011-11-14 | 2012-08-27 | 2013-03-01 |
| **Parameter** | **Units** | | | | | | | | | | | | | |
| Dissolved Aluminum | ug/L | 26 | 9 | 16 | 9 | 6 | 9 | 11 | 15 | 17 | 19.3 | 5.6 | 20 | 12.5 |
| Dissolved Antimony | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Arsenic | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | 0.1 | <1 | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Barium | ug/L | 18 | 13 | 17 | 16 | 15 | 19 | 18 | 18 | <20 | <20 | <20 | <20 | <20 |
| Dissolved Beryllium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <0.1 | <5 | <1 | <1 | <1 | <1 |
| Dissolved Bismuth | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <1 | n/a | n/a | n/s | n/s | n/s |
| Dissolved Boron | ug/L | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | 50 | <50 | <100 | <100 | <100 | <100 | <100 |
| Dissolved Cadmium | ug/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.05 | <0.01 | <0.05 | <0.017 | <0.017 | <0.017 | <0.01 |
| Dissolved Calcium | ug/L | 17900 | 14900 | 15900 | 15900 | 16900 | 19400 | 19900 | 16900 | 16500 | 15200 | 16700 | 18600 | 16000 |
| Dissolved Cesium | ug/L | - | - | - | - | - | - | < 0.5 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Chromium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <1 | <0.5 | <1 | <1 | <1 | <1 |
| Dissolved Cobalt | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <0.5 | <0.5 | <0.3 | <0.3 | <0.3 | <0.3 |
| Dissolved Copper | ug/L | 2 | < 1 | < 1 | < 1 | < 1 | 1 | < 0.5 | 0.7 | <1 | <1 | <1 | <1 | <1 |
| Dissolved Iron | ug/L | 70 | < 50 | 50 | < 50 | < 50 | < 50 | < 50 | 47 | 68 | 32 | 176 | <30 | 40 |
| Dissolved Lead | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.25 | <0.2 | <0.1 | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Lithium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | 4 | <5 | <5 | <5 | <5 | <5 | <5 |
| Dissolved Magnesium | ug/L | 1820 | 1340 | 1740 | 1530 | 1590 | 1960 | 2190 | 1780 | 1870 | 1620 | 1780 | 1970 | 1700 |
| Dissolved Manganese | ug/L | < 1 | 11 | 2 | 4 | 26 | 21 | 47 | 21 | 23 | 10.5 | 4.36 | <0.3 | 18.2 |
| Dissolved Mercury | ug/L | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | < 0.02 | <0.02 | <0.2 | <0.01 | <0.01 | <0.01 | <0.01 |
| Dissolved Molybdenum | ug/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | <1 | <1 | <1 | <1 | <1 | <1 |
| Dissolved Nickel | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | <1 | <5 | <1 | <1 | <1 | <1 |
| Dissolved Phosphorus | ug/L | < 150 | < 150 | < 150 | < 150 | < 150 | < 150 | < 75 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Potassium | ug/L | 300 | 300 | 300 | 300 | 300 | 400 | 360 | 320 | n/a | <2000 | <2000 | <2000 | <2000 |
| Dissolved Selenium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | <0.1 | <1 | <1 | <1 | <1 | <1 |
| Dissolved Silicon | ug/L | 900 | 1900 | 1500 | 2100 | 1300 | 2200 | 1700 | 2940 | n/a | n/a | n/a | n/a | n/a |
| Dissolved Silver | ug/L | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.2 | <0.02 | <0.05 | <0.02 | <0.02 | <0.02 | <0.02 |
| Dissolved Sodium | ug/L | 7320 | 6420 | 7270 | 6850 | 6910 | 8830 | 9950 | 7550 | 8000 | 7100 | 7800 | 8300 | 7800 |
| Dissolved Strontium | ug/L | 48 | 44 | 47 | 49 | 48 | 55 | 55 | 47 | n/a | n/a | n/a | n/a | n/a |
| Dissolved Tellurium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Thallium | ug/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | <0.05 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Dissolved Thorium | ug/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.25 | n/a | n/a | n/a | n/a | n/a | n/a |
| Dissolved Tin | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <5 | n/a | <0.5 | <0.5 | <0.5 | <0.5 |
| Dissolved Titanium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | <5 | <50 | <10 | <10 | <10 | <10 |
| Dissolved Uranium | ug/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.25 | <0.1 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Dissolved Vanadium | ug/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.5 | <5 | <30 | <1 | <1 | <1 | <1 |
| Dissolved Zinc | ug/L | < 5 | < 5 | 9 | < 5 | < 5 | < 5 | < 5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Dissolved Zirconium | ug/L | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 0.5 | <0.5 | n/a | n/a | n/a | n/a | n/a |

**Laboratory Analytical Results - Monitoring Locations SWMP-06 and WET-01**

| Sample ID | | SWMP-06 | SWMP-06 | SWMP-06 | SWMP-06 | SWMP-06 | SWMP-06 | SWMP-06 | SWMP-06 | SWMP-06 | SWMP-06 | SWMP-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date (Y/M/D) | | 2007 11-13 | 2008 04-24 | 2008 10-20 | 2009 04-20 | 2009-11-13 | 2010-05-03 | 2010-12-20 | 2011-05-09 | 2011-11-14 | 2012-08-27 | 2013-03-01 |
| **Parameter** | **Units** | | | | | | | | | | | |
| Total Suspended Solids | mg/L | 2 | 1 | <1 | 2 | 1 | <4 | <3 | <3 | <3 | 3.6 | <3 |
| Turbidity | NTU | 1.7 | 1.1 | 1.2 | 1.5 | 1.1 | 2.5 | 2.01 | 2.18 | 1.93 | 1.04 | - |

| Sample ID | | WET-01 | WET-01 | WET-01 | WET-01 | WET-01 | WET-01 | WET-01 | WET-01 | WET-01 | WET-01 | WET-01 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date (Y/M/D) | | 2007 11-13 | 2008 04-24 | 2008 10-20 | 2009 04-20 | 2009-11-13 | 2010-05-03 | 2010-12-20 | 2011-05-09 | 2011-11-14 | 2012-08-27 | 2013-03-01 |
| **Parameter** | **Units** | | | | | | | | | | | |
| Total Suspended Solids | mg/L | 7 | 2 | 7 | 2 | 3 | <4 | <3 | <3 | 5.8 | 10.8 | <3 |
| Turbidity | NTU | 17 | 3 | 20 | 2 | 8 | 3.2 | 3.51 | 3.70 | 22.5 | 42.0 | - |

# APPENDIX II

Enos Lake and Enos Lake Wetland

**March 2013 Analytical Laboratory Report**

KERR WOOD LEIDAL
consulting engineers

Appendix C

# PGL
# Terms of Reference – Enos Lake Protection & Monitoring Program

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Vancouver, BC Canada V6E 4E6
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# Memo

PGL File #: 0130-12.04

DATE: Oct 2/13 (revised)

**Re: Terms of Reference – Enos Lake Protection and Monitoring Program**

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Enos Lake is an integral part of the natural environment of the Lakes District, as described in the Environmental Impact Assessment prepared by Pottinger Gaherty Environmental Consultants Ltd. (PGL) (February 2010), and the Integrated Stormwater Management Plan (ISMP) (KWL, 2013). The Lakes District Neighbourhood Plan (February 2011) includes a policy for the development and implementation of an Enos Lake Protection and Monitoring Program (the Program) to monitor potential effects from the development of the Lakes District. The purpose of the ISMP is to mitigate these possible effects on the lake through stormwater management design. The Program will be developed and implemented to verify the effectiveness of the ISMP to manage Enos Lake water quality and quantity.

Section 3.2.2 of the Lakes District Neighbourhood Plan outlines the policies for the proposed Regional Park, including:

> f. In conjunction with the landowner and the appropriate federal and provincial agencies and according to a schedule outlined within the PDA, develop an Enos Lake Protection and Monitoring Program which includes, but is not limited to: base line water quality monitoring and assessment acceptable to the provincial Ministry of Environment (MoE); support in the development of site specific Water Quality Objectives for Enos Lake based on MoE protocols; and guidelines for invasive species management practices.

This "Terms of Reference" document outlines the objectives of the Program, timing and responsibilities, and an overview of the steps that will be involved in designing the Program and achieving the above policy.

Note that the Program will be designed to be implemented through all three phases of the development: pre-project, construction and post-project. The responsibility for implementation of the monitoring program will shift over time, but the integrity of the design will be consistent.

## BACKGROUND

Enos Lake is a small lake in a mostly undeveloped area of the Fairwinds Community located in Nanoose Bay, BC. The lake is about 18ha, with a watershed of about 235ha. About 12ha of the watershed has already been developed and a further 86ha are scheduled for future development over several phases (over an estimated 10–20 years). Almost half the watershed (112ha) is designated for conservation and passive recreational uses, and will remain undeveloped as a public park. Surface inlet streams to the Lake are minor and are generally seasonal. The lake discharges at its outlet to Enos Creek. The outlet of the lake has a weir structure to maintain water levels. The weir was installed in 1956 and upgraded in 1994. The outlet also has Water Licenses for storage and irrigation that are in place for use by the Fairwinds golf course.

## OBJECTIVES

The overall intent of the Program is to monitor (a) the effectiveness of the ISMP relative to significant changes to the water quality and quantity in Enos Lake, and (b) inform decisions regarding water management as required. Criteria for the quality and quantity of stormwater from developed areas entering the lake will be set. Stormwater-management design measures are proposed to meet the objectives set by standard government guidance for land development, including the BC Stormwater Guidebook (2002) and the Department of Fisheries and Oceans Canada (DFO) Land Development Guidelines (1993).

The specific tasks to develop and implement the Program include:

1. Compilation and review of past historical environmental data for Enos Lake;
2. Detailed design of a sampling program, including selection of key monitoring parameters and thresholds;
3. Establishment of a environmental baseline profile; and
4. Implementation of an environmental sampling program during the build out of the neighbourhood and the post project follow-up component.

### 1. Historical Water Quality Data

The water quality data that exists for Enos Lake was largely obtained through monitoring that was conducted for Fairwinds over the last several years to verify stormwater management. An initial compilation and review of this data will be essential to establish historical background conditions for the monitored parameters. The data will provide an understanding of past changes in the Enos Lake limnology and provide a baseline for comparison with post-development monitoring in the future. Based on a review of the data by an aquatic ecologist, additional pre-development sampling may be recommended to substantiate the baseline knowledge.

### 2. Design the Program

The Program design will need to consider past data collected for Enos Lake and identify the specific locations and parameters to appropriately monitor the effectiveness of the ISMP. The Program will be designed to be practical, focused and defensible in its ability to detect significant changes (should they occur) to the water quality and quantity of the lake. It will be structured to clearly identify pre-project, project and post-project monitoring.

Qualified environmental specialists, with input from a lake ecologist, should design the Program. Interested parties, such as the Community Advisory Group, can be consulted on the program design. MOE and RDN would review the draft Program design.

The Program will include typical water quality parameters following standard limnology study procedures. Preliminary indications are that the parameters of interest would be turbidity, light transmission, total suspended solids, nutrients, temperature, and water level. The Program design will provide a detailed outline of the locations and timing (e.g., seasonal, monthly) of environmental monitoring for each parameter. The sampling program should follow guidelines set out in the BC Resources Information Standards Committee protocols:

- *Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia* (1998);
- Ambient Freshwater and Effluent Sampling Manual (1997); and
- Guidelines for Interpreting Water Quality Data (1998).

The sampling plan should also include observations for invasive species and their proliferation.

### 3. Establish Baseline & Thresholds

The next step will be to establish the baseline conditions of the lake, prior to land-clearing activities. This would include pre-development levels and variations for all key parameters identified in the study design. The historical data from Task 1 should be analyzed and reported to establish the baseline conditions for (i) the parameters of concern, (ii) at the locations for future monitoring, (iii) over a full calendar year prior to initial land clearing for development. If gaps are identified, then new data should be collected.

Each parameter will be assigned site-specific target thresholds based on baseline data and government guidance for water quality objectives. Depending on the parameter, thresholds may vary over the year and with location. The thresholds will be linked with triggers for additional attention if a specific parameter has exceeded an established threshold. In this event, mitigation options may be required, including changes to the ISMP. This decision framework will be outlined at this step.

## 4. Implement the Program

Sampling will be repeated at the determined frequency on an ongoing basis, and the results will be compiled and analyzed annually. Trends in environmental quality parameters over time can be plotted to monitor the status of the lake's environmental quality and its performance against standards. Should the Program identify that water quality objectives are not being met, an R.P.Bio. will review the results and, if appropriate, discuss possible actions that could be applicable to future phases. A third-party review by a Registered Professional Biologist may be considered to verify these conclusions, following each season's sampling event.

The results will be provided annually to all interested parties.